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BUILDING HEATING ENERGY CONSUMPTION AT FIXED FACILITIES.(U)
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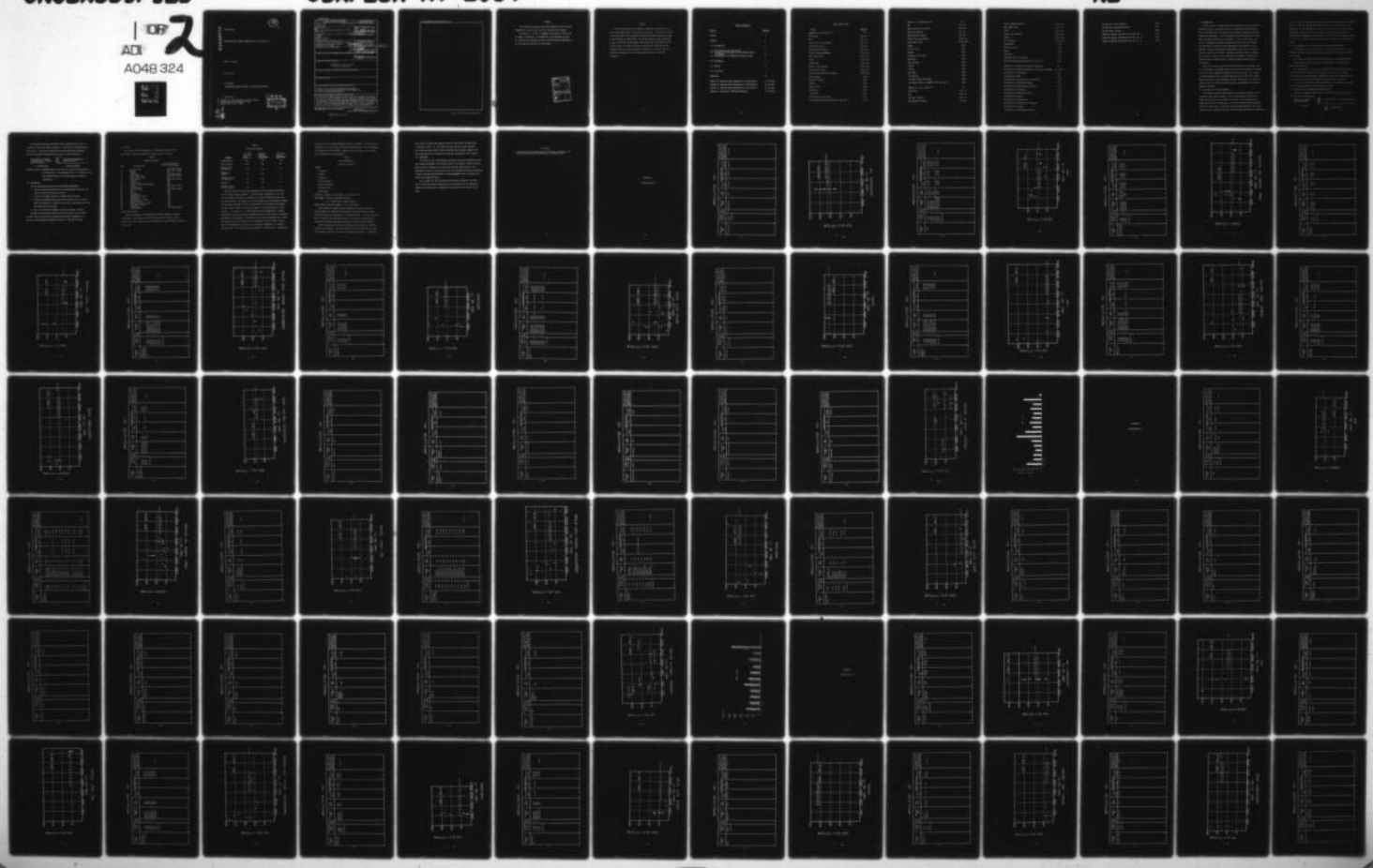

FESA-RT-2034

BUILDING HEATING ENERGY CONSUMPTION AT FIXE

Mounir M. Botros

20 June 1977

Final Report

APPROVED FOR PUBLIC RELEASE, DISTRIBUTION

Prepared by

USA Facilities Engineering Support Agency
Research and Technology Division
Fort Belvoir, VA 22060

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The total average of heating consumption (the average line)
The baseline of heating consumption

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Oil delivery data were collected for twenty-four building types at three Army installations in the Washington, DC area. These data, collected for FY 75 and FY 76, were analyzed to determine the heating energy consumed by the different building types. The average heating energy consumption as well as the high and low samples were calculated and plotted for each building type. The report provides a basis for determining where the application of energy conservation techniques and the use of energy control systems is most cost effective.

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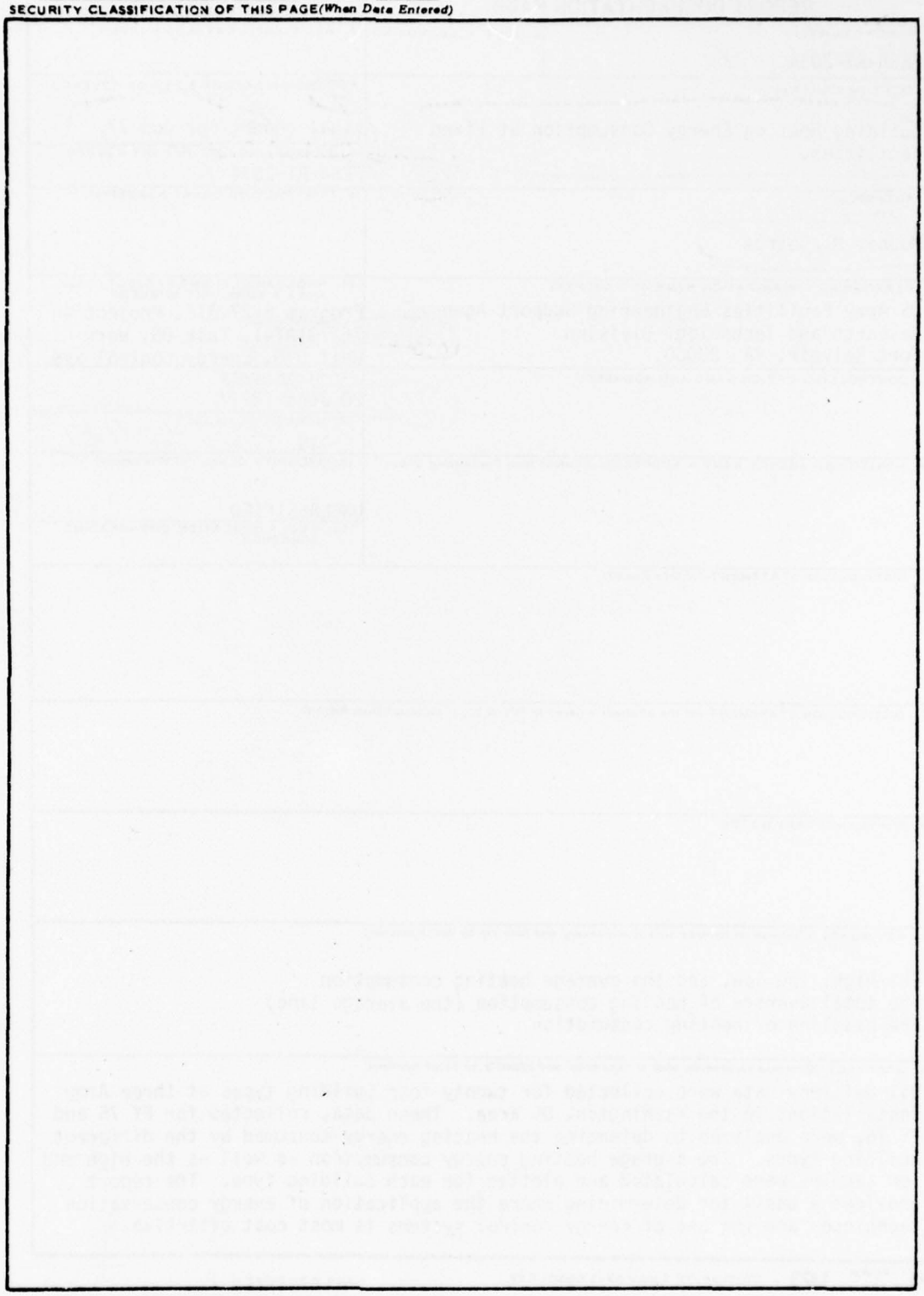
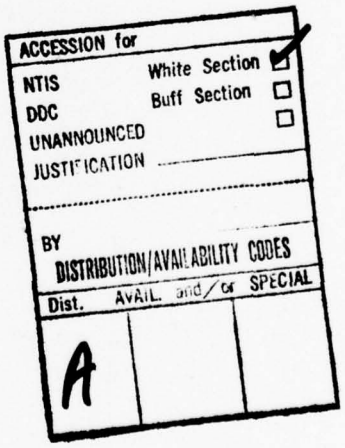


PREFACE

This report was prepared under RDT&E program 6.27.31A, project 4A762731AT41, task 06, work unit 010, Energy Control Systems.

COL James R. C. Miller is Commander and Director of FESA, and Mr. Homer D. Musselman is Chief/Research and Technology Division. Mr. James Walton (DAEN-FEU-A) and Mr. Harrison Maschke (DAEN-MCE-U) are the technical monitors for the project.



Summary

Oil delivery data were collected for twenty-four building types at three Army installations in the Washington, DC area. These data, collected for F&75 and FY76, were analyzed to determine the heating energy consumed by the different building types. The average heating energy consumption as well as the high and low samples were calculated and plotted for each building type. The report provides a data base for determining where the application of energy conservation techniques is feasible and cost effective and where the use of energy control systems is mot cost effective.

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TABLES AND FIGURES

1.0 INTRODUCTION

A major problem in establishing cost effectiveness of energy control systems and energy conservation ideas is to determine how much energy a building consumed before the energy control system or energy conservation concept was implemented. This is especially true at Army fixed facilities where individual buildings are not metered. In order to provide a data base on load demand and energy consumed by building type, an extensive building metering program has been undertaken at Forts Belvoir, Carson and Hood. Energy consumption and load demand data will be available in FY79 as a result of this effort. However, this type of data is required now in order to establish cost effectiveness and payback of energy conservation ideas and energy control systems currently being planned or implemented.

While individual buildings at fixed facilities are not metered, fuel oil is delivered to individual tanks and oil delivery receipts are recorded at the Facilities Engineering Directorate at each facility. As a result of collecting data from oil delivery receipts for FY75 and FY76 at three Army installations in the Washington, DC area, FESA was able to perform an analysis that is indicative of heating energy requirements for different types of buildings.

2.0 DATA COLLECTION AND PREPARATION

The buildings selected were checked for functional occupancy as well as heated space (square footage). The oil delivered to a building was divided by the total square footage to provide a gross consumption per square foot for each building type. Similar buildings were then analyzed to obtain a high value, a low value and the average consumption per square foot per year for each building type for which data were available (Appendixes

A, B, C). The data from the three installations were combined using a weighting factor to obtain the heating energy consumption for a building type in the Washington, DC area (Appendix D). The data presented in this report could be normalized on the basis of heating degree days thus direct consumption or extrapolation of consumption can be made by inference by square footage. Pages D-23, 24, 25 are plots of the three installations compared to the area base-lines.

2.1 CALCULATION OF THE HIGH, LOW AND AVERAGE HEATING CONSUMPTION

Oil consumption for each of two years was obtained and combined. The average consumption for each building was obtained by dividing by two giving gallons/year.

This number was then multipled by the BTU's/gallon yielding BTU's/year.

The BTU's/year then divided by the square footage of the building to obtain BTU's/ft^2/year.

All the buildings of a class on an installation were separated to give the high and low consumption. The average for that class of buildings on an installation was obtained by summing the total BTU's consumed per ft^2/year and dividing by the total number of the buildings for this area.

If the sample consisted of just one building, (its) consumption is used as the average consumption for that type of building.

2.2 CALCULATION OF THE COMBINED INSTALLATION DATA

The total average heating consumption in BTU/ft^2/year for each type of building was calculated using:

$$\text{The total average or the average line} = \frac{\sum_{i}^{n} \text{building areas}_i \times \text{average consumption}_i}{\sum_{i}^{n} \text{building areas}}$$

i = building

The baseline data were calculated using a weighting factor which is a function of the total square footage of a particular building type at an installation. The use of a weighting factor precluded the information from one installation masking the data from a second installation.

$$\text{The baseline of heating consumption for a specific type of building} = \frac{\sum_{i=1}^{n=3} (\text{installation consumption}_i \times \text{weighting factor})}{}$$

i = installation

weighting factor

Weighting factor = weighting factors were derived for each building type at an installation. The weighting factor is a function of the total square footage of a building type at a specific installation.

3.0 ASSUMPTIONS

The data presented are based on the following assumptions:

1. The oil was actually delivered to the specified building tank and receipts reflect the correct building.
2. There is no leakage from the oil tanks and no spillage.
3. A specific building could be off by two tanks of fuel in the two years studied and is a function of the fuel in the tank at the start and finish of FY75 and FY76.
4. The oil was actually consumed in the time period of interest.

The data and conclusions should be applied cautiously since single building samples do not reflect averages and building consumptions is a function of the mechanical equipment located in a specific building.

4.0 RESULTS

The average heating consumption by building type for the three installations ranked from highest to lowest is given in Table 1:

TABLE 1

Ranked Consumption

Rank	Building Type	Heating Consumption* BTU x 10^3/sq ft/year
1	Fire Station	323 single sample
2	Museum	302 single sample
3	Theater	213
4	Gymnasium	213 single sample
5	Band Auditorium	210 single sample
6	Motor Repair Shops	176
7	Field House	169 Single sample
8	Chapels	156
9	EM Barracks	136
10	General Instructional Bldgs.	123
11	Library	117 single sample
12	Post Exchange	106
13	Officer's Mess	102 single sample
14	BOQ	102
15	EM Mess	101
16	Laboratories	100
17	Recreational Center	99
18	Warehouses	93
19	EM Barracks with Mess	89
20	Admin Offices	86
21	Officer's Family Housing	85
22	NCO Family Housing	64
23	Commissary	41
24	Bowling Alley	36 single sample

*Values were rounded

Table 2 delineates the distribution of thermal energy at a typical installation. The percent of building space is given relative to the percent of the total heating space requirement for seven different categories of buildings.

TABLE 2

Building Consumption

Category	% of Total Building Space	Relative Heating Requirement	% of Total Heating Requirement
Troop Housing	32.5	1.00	30
Family Housing	27.9	1.45	36
Administration & Training	11.8	1.10	12
Hospital & Medical	3.7	1.20	4
Community Service & Commercial	7.1	1.30	8
Storage	7.6	.65	4
Maintenance Production & Misc.	9.4	.75	6

The study results indicate that community service and repair facilities are the largest energy consumers. The high energy consumption by fire stations and repair facilities is probably due to high ceilings and large doors at these buildings. The community service category and the maintenance category building types represent 14% of an installation's total thermal requirements, but only a small fraction of the total number of buildings found at a fixed facility. As a result, it is anticipated that the implementation of energy conservation concepts and energy management systems in these types of buildings would have a high payback. The ranking and the energy consumption for a given building type will be affected by the consumption factors in Table 3 and may offer an explanation as to the high or low energy consumption of a specific building type. All of these factors contribute to the diversity in consumption

between types of buildings and within types of buildings. Calculating the consumption on a foot-cubed (ft^3) basis would narrow the difference between the highest and lowest ranking. However, for the purpose of this report, this information was not developed.

TABLE 3

(From Reference 1)

Factors of Energy Use

PRIMARY

- Equipment
- Climate
- Population
- Building Volume
- Age and Condition
- Functional Use
- Construction

SECONDARY - Operation, time element, i.e., mode of use

THIRD ORDER - Internal and external effects

- i.e., steam supply, radient effects

FOURTH ORDER - Parasitic effects - i.e., pilot lights

Troop housing and family housing represent the major consumers of thermal energy at a fixed facility because of the large number of these buildings found at an installation. A review of Table 1 in conjunction with Table 2 indicates that "Barracks" types of buildings would be promising candidates for energy conservation measures and energy control systems.

Family housing was the lowest building consumer category at the three installations examined. This could imply that military families are aware of the energy crisis and are practicing energy conservation. In performing

the analysis a discernible trend was noted in that energy consumption was a function of rank, i.e., the higher the rank the more energy consumed. This effect was noted both in Officer and NCO family housing, however, the data collected were not sufficient to draw any conclusions in this report.

5.0 CONCLUSION

The results of this investigation provide a data base of determining the heat energy requirements for different types of buildings at fixed facilities. While the data is based on oil deliveries to three installations in the Washington, DC area, it can provide a basis for implementing energy conservation concepts and selecting buildings for energy management control systems until better data become available.

From a study like this the baseline of heating consumption for every type of building on Army installations can be estimated and the comparison between the installation's consumption and the baseline consumption can be made.

REFERENCES

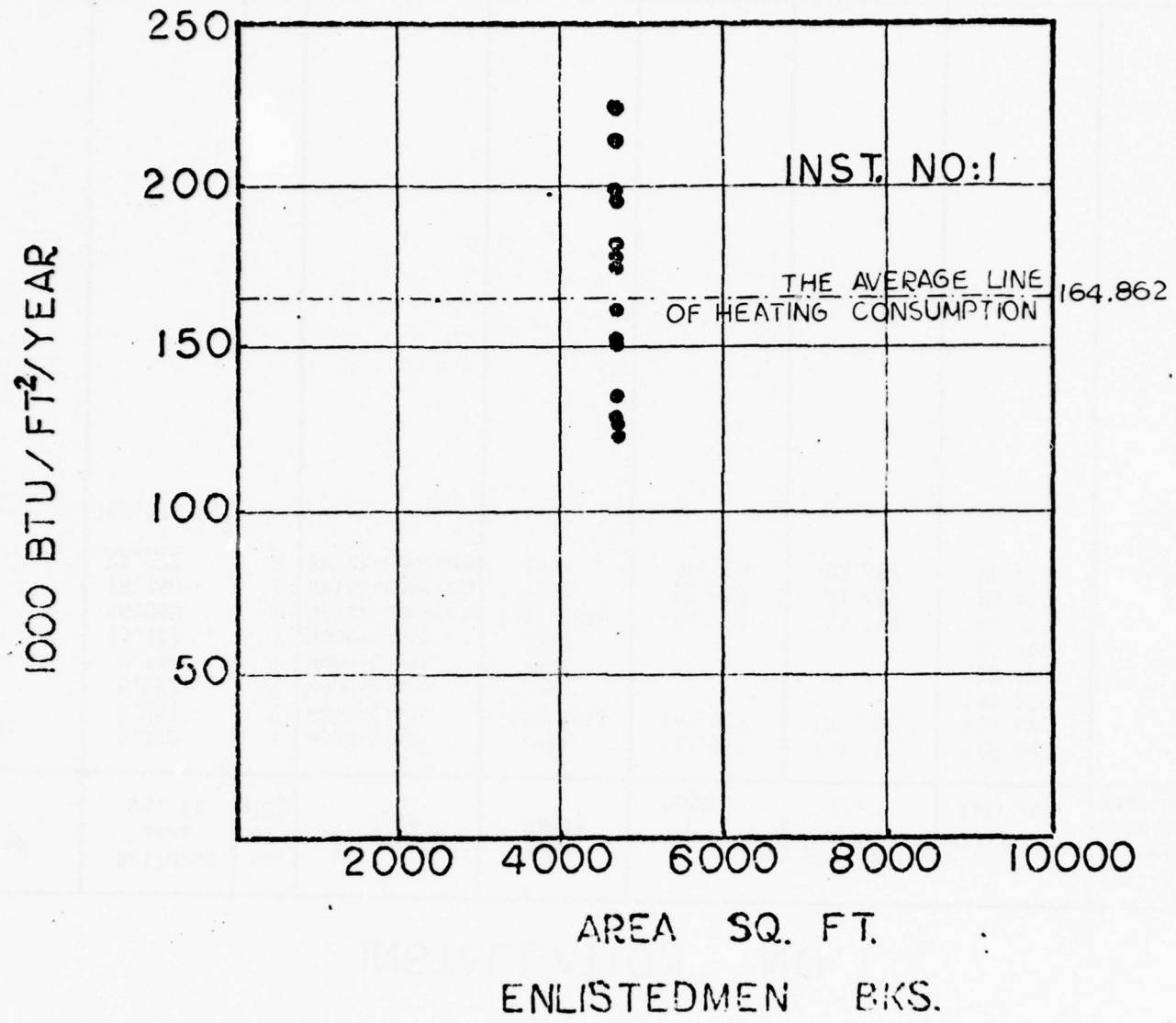
1. Characterization of Energy Usage on Military Installations, USA Facilities Engineering Support Agency, 22 October 1974.

APPENDIX A

INSTALLATION NO. 1

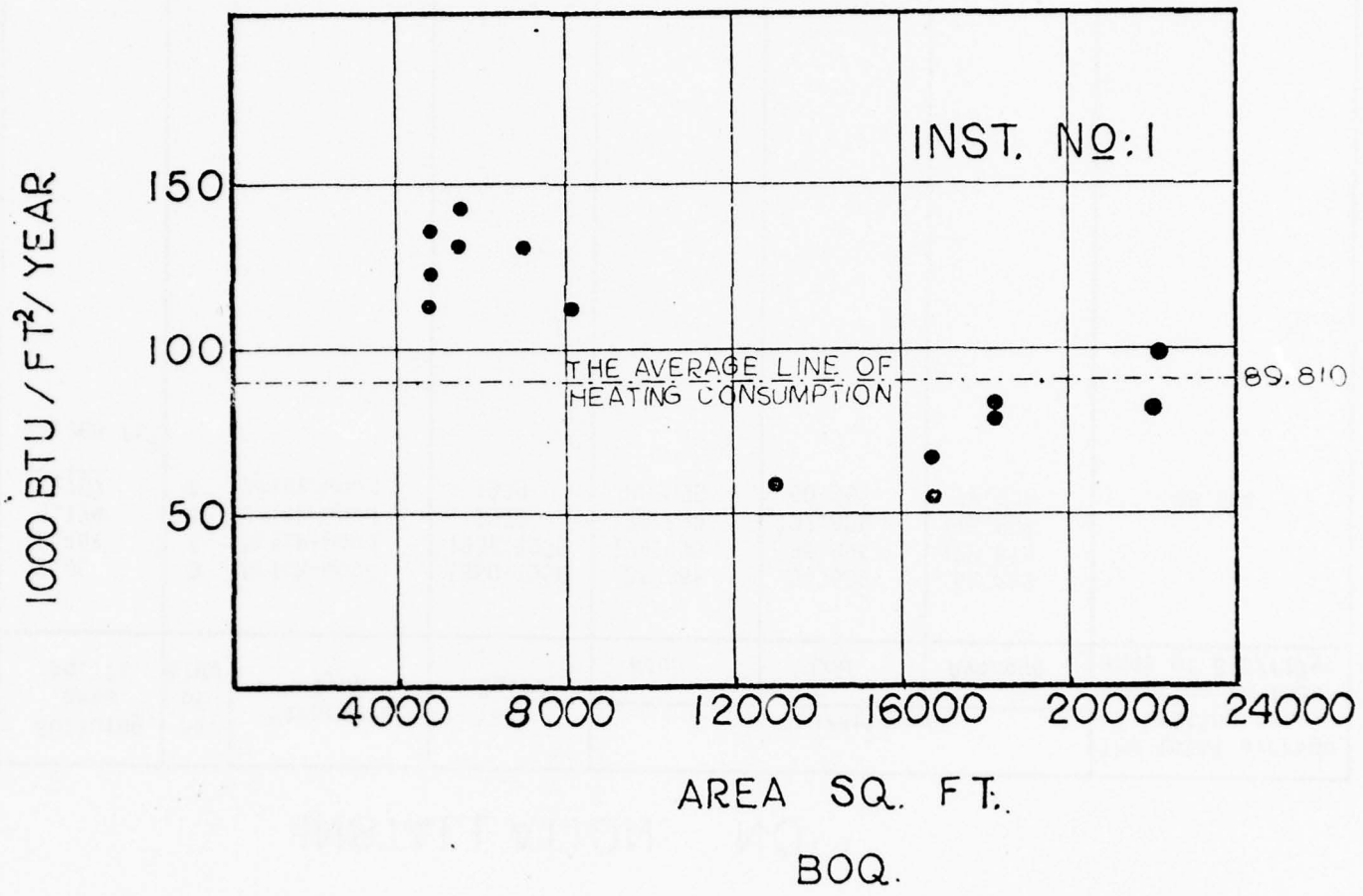
INSTALLATION NO: 1

Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
EM Barracks	4,720 75,520 ft^2	16	Wood-glass	1941	227.708	125.570	164.862	164 862


250
200
150
100
50
INST. NO:1
THE AVERAGE LINE
OF HEATING CONSUMPTION
164.862
1000 BTU/FT²/YEAR
2000
4000
6000
8000
10000
AREA SQ. FT.
ENLISTEDMEN BKS.

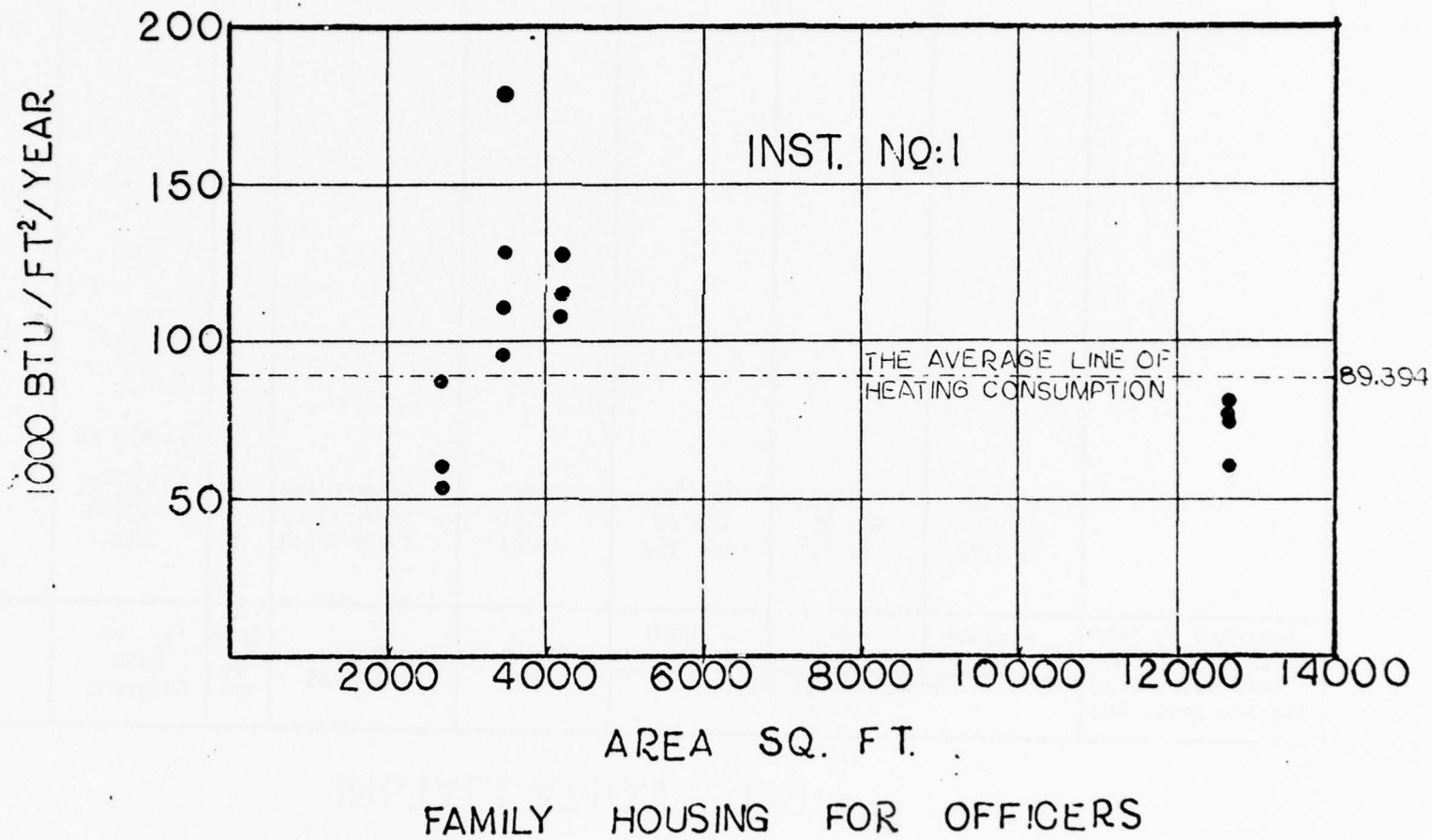
INSTALLATION NO: 1

Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
BOQ	4,720	3	Wood-glass	1941	137.968	114.150	125.693	
	5,385	2	Wood-glass	1940-1941	145.043	132.200	138.622	
	6,962	1	Wood-glass	1941			131.815	
	8,142	1	Wood-glass	1941			113.408	
	13,117	1	Wood-glass	1942			60.709	
	16,800	2	Brick-concrete	1947-1948	68.275	55.154	61.715	
	18,360	2	Brick-concrete	1969	85.357	81.472	83.415	
	22,272	2	Brick-concrete	1956	98.908	82.606	90.757	89.810
	168,015 ft^2							


INST. NO:1
150
100
50
THE AVERAGE LINE OF HEATING CONSUMPTION
89.810
1000 BTU / FT² / YEAR
4000
8000
12000
16000
20000
24000
AREA SQ. FT.
BOQ.

INSTALLATION NO: 1

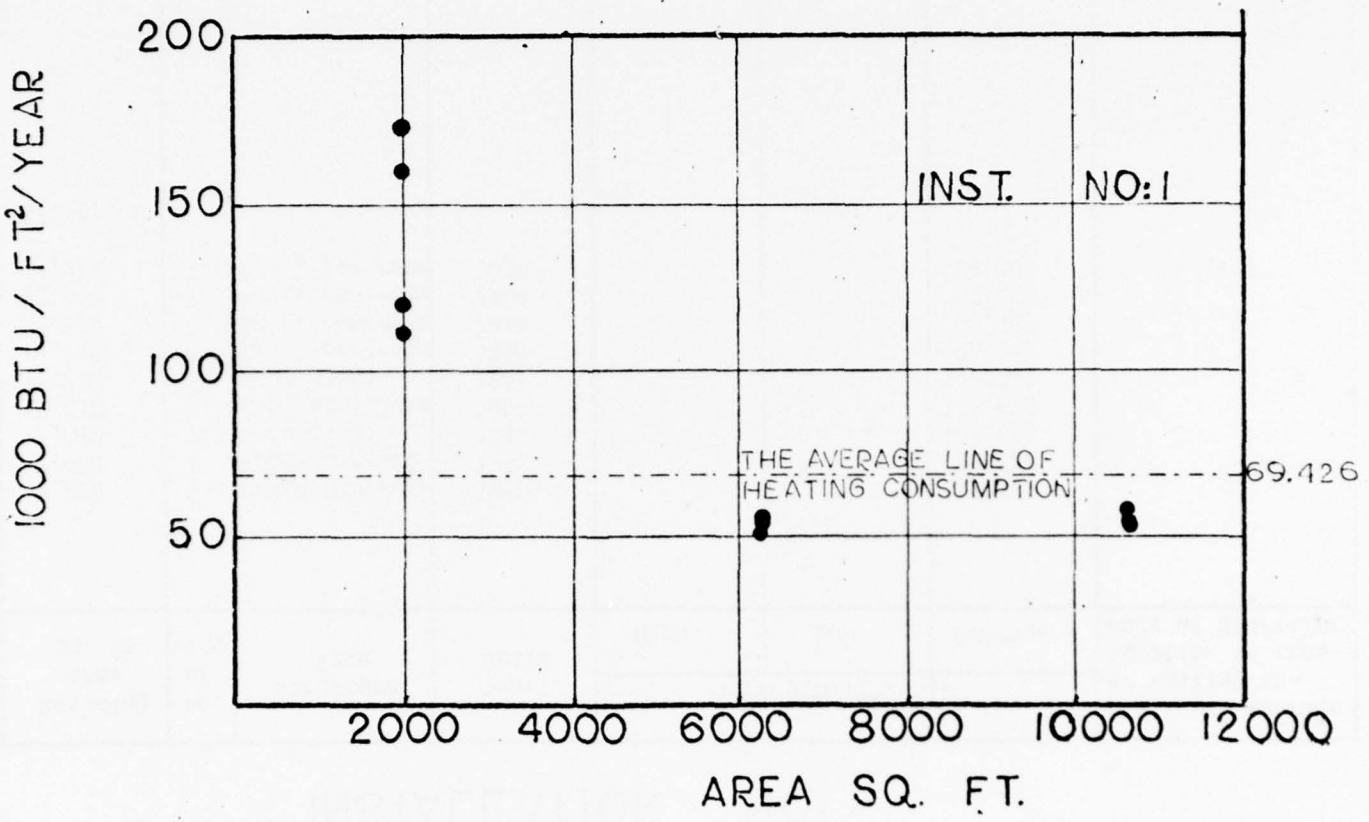
Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thouands of BTU/ft^2/yr
					High	Low	Average	
Family housing for officers	2,660	3	Brick-wood	1950-1956	88.368	54.552	68.289	
	3,461	4	Brick-wood	1934-1935	179.195	96.596	128.815	
	4,179	4	Brick-wood	1947	128.509	107.805	116.905	
	12,707	4	Brick-wood	1939	80.995	60.965	72.923	89.394
	89,368 ft^2							



FAMILY HOUSING FOR OFFICERS

INSTALLATION NO: 1

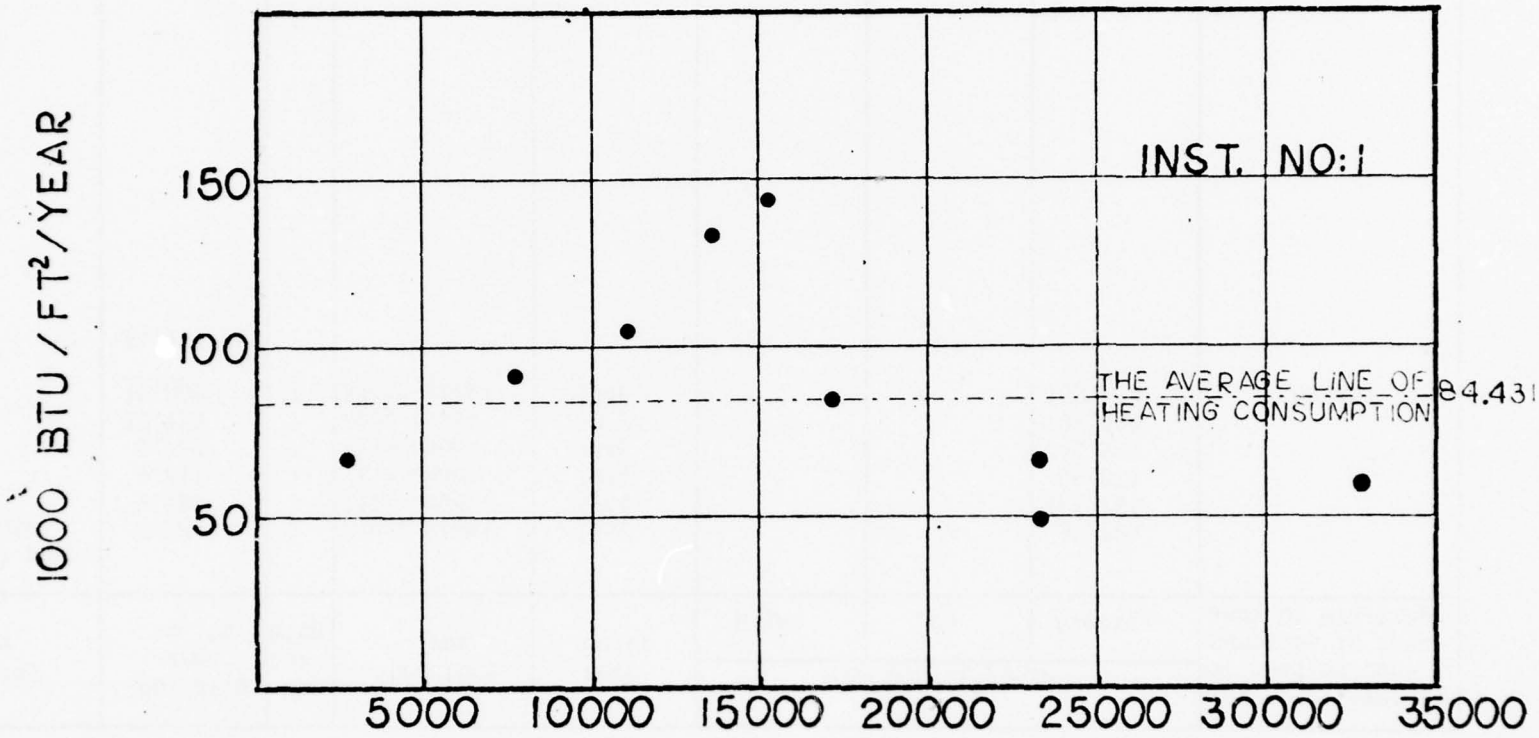
Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
NCO Family Housing	1,946	4	Brick-wood	1930	174.100	112.661	152.158	
	6,305	3	Brick-wood	1956	57.731	52.935	55.707	
	10,705	3	Brick-wood	1956	58.510	56.614	57.453	69.426
	58,814 ft^2							



NCO FAMILY HOUSING

INSTALLATION NO: 1

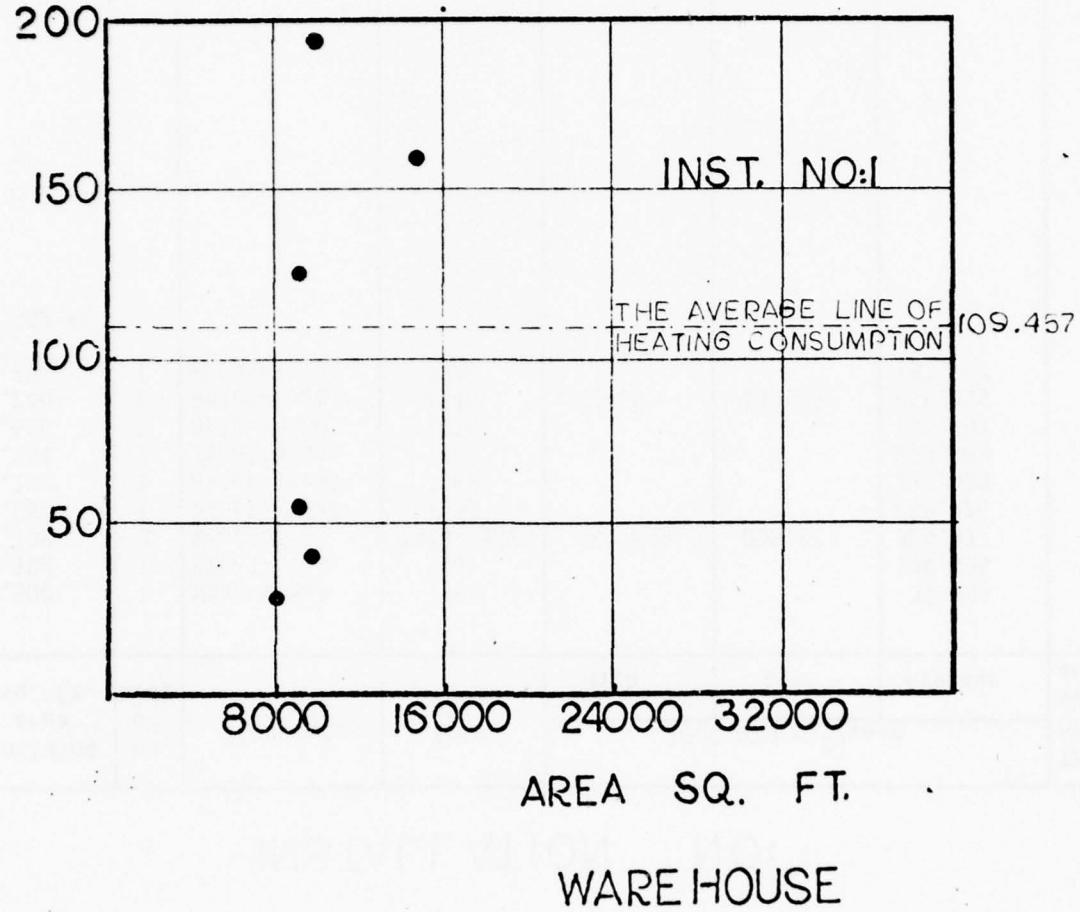
Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
Administration General Purpose Offices	2,825	1	Brick-concrete	1960			67.348	
	7,680	1	Wood-concrete	1942			93.023	
	11,080	1	Wood-glass	1943			107.805	
	13,618	1	Concrete-glass	1954			136.638	
	15,237	1	Wood-glass	1941			147.341	
	17,146	1	Brick-concrete	1935			88.947	
	23,513	1	Brick-concrete	1932			50.407	
	23,667	1	Brick-concrete	1964			67.595	
	32,913	1	Brick-concrete	1928			59.361	84.431
	147,679 ft^2							



ADMINISTRATION GENERAL PURP. OFFICES

INSTALLATION NO: 1

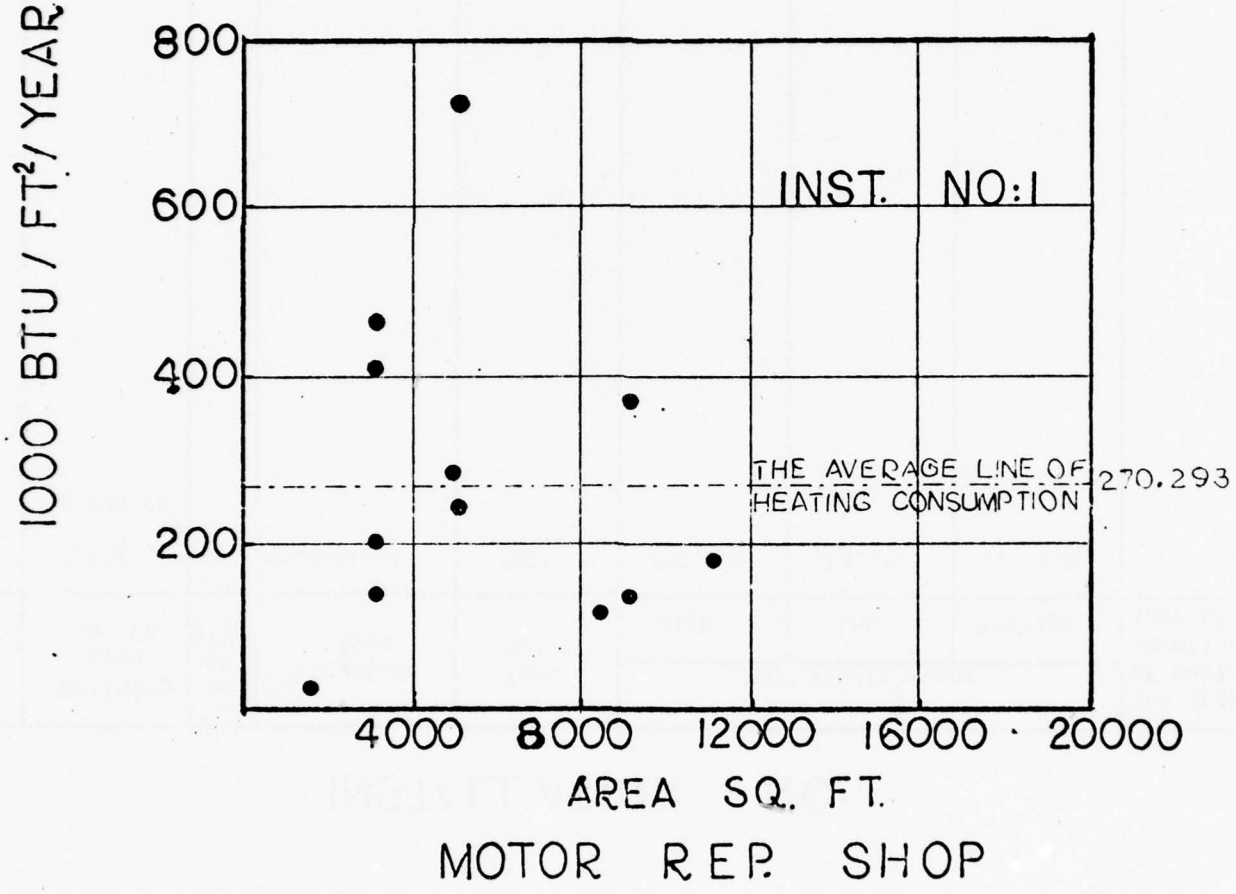
Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
General purp. warehouse	7,982	1	Block-steel	1955			31.290	
	9,120	1	Tile-wood	1944			125.754	
	9,211	1	Tile-wood	1944			55.074	
	9,720	1	Tile-wood	1946			40.581	
	10,126	1	Wood-glass	1917			195.303	
	15,000	1	Block-steel	1946			161.219	109.457
	61,159 ft^2							


200
150
100
50
1000 BTU / FT²/YEAR
INST. NO:1
THE AVERAGE LINE OF HEATING CONSUMPTION
109.457
8000
16000
24000
32000
AREA SQ. FT.

WARE HOUSE

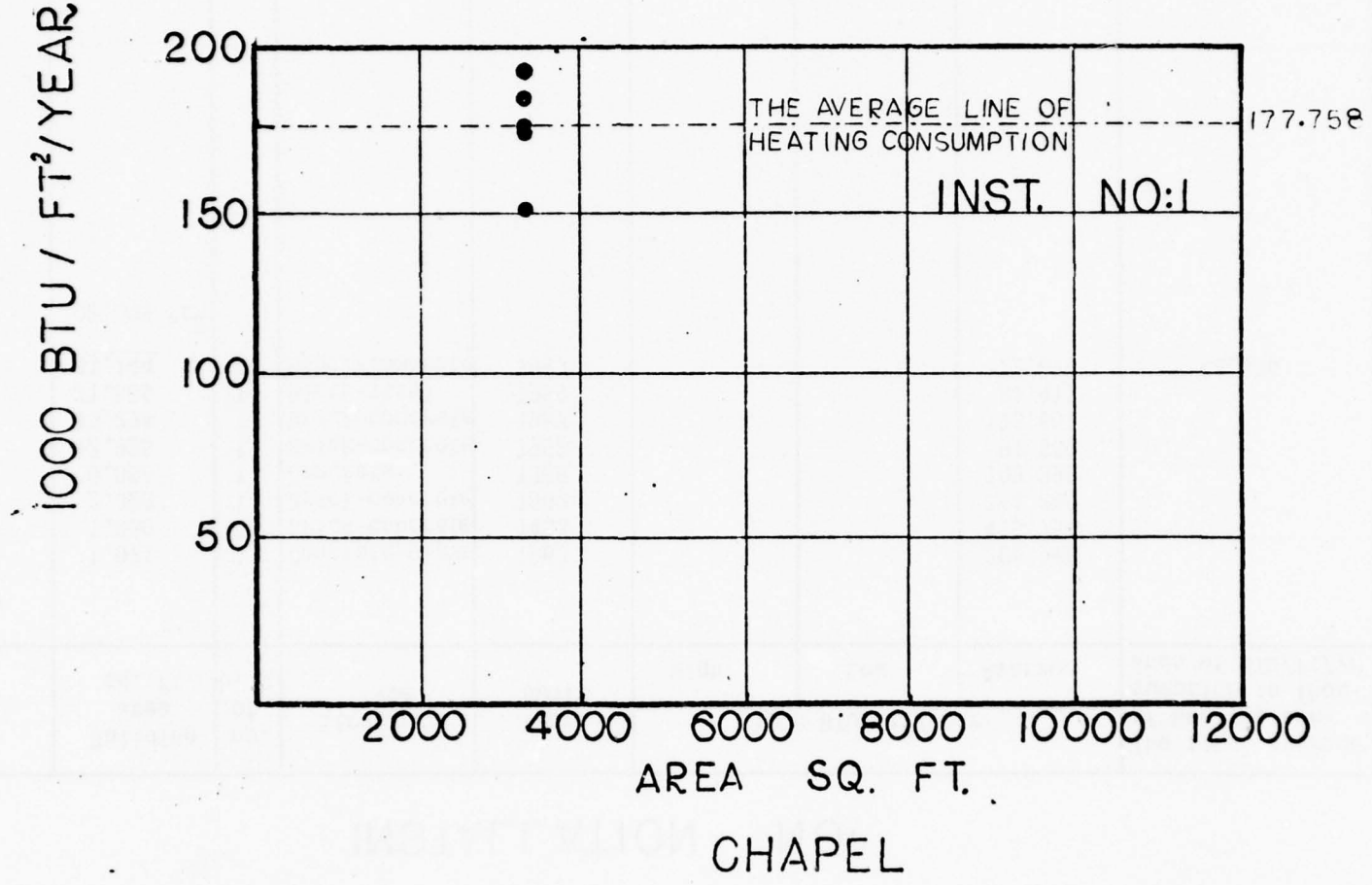
INSTALLATION NO: 1

Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
Motor repair shop	1,500	1	Wood-steel	1955			31.733	
	3,108	1	Steel-glass	1941			144.436	
	3,108	3	Wood-glass	1940-1942	469.649	205.923	364.477	
	5,060	1	Block-steel	1963			288.826	
	5,103	1	Block-steel	1963			731.099	
	5,151	1	Steel-glass	1966			244.503	
	8,556	1	Brick-wood	1939			122.107	
	9,240	2	Brick-wood	1940	374.5	139.272	256.886	
	11,220	1	Wood-glass	1945			187.767	270.293
	67,502 ft^2							


1000 BTU / FT² / YEAR
800
600
400
200
INST. NO:1
THE AVERAGE LINE OF HEATING CONSUMPTION
270.293
4000
8000
12000
16000
20000
AREA SQ. FT.
MOTOR REP. SHOP

INSTALLATION NO: 1

Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thouands of BTU/ft^2/yr
					High	Low	Average	
Chapel bldg	3,278 16,390 ft^2	5	Wood-glass	1941	194.752	152.492	177.758	177.758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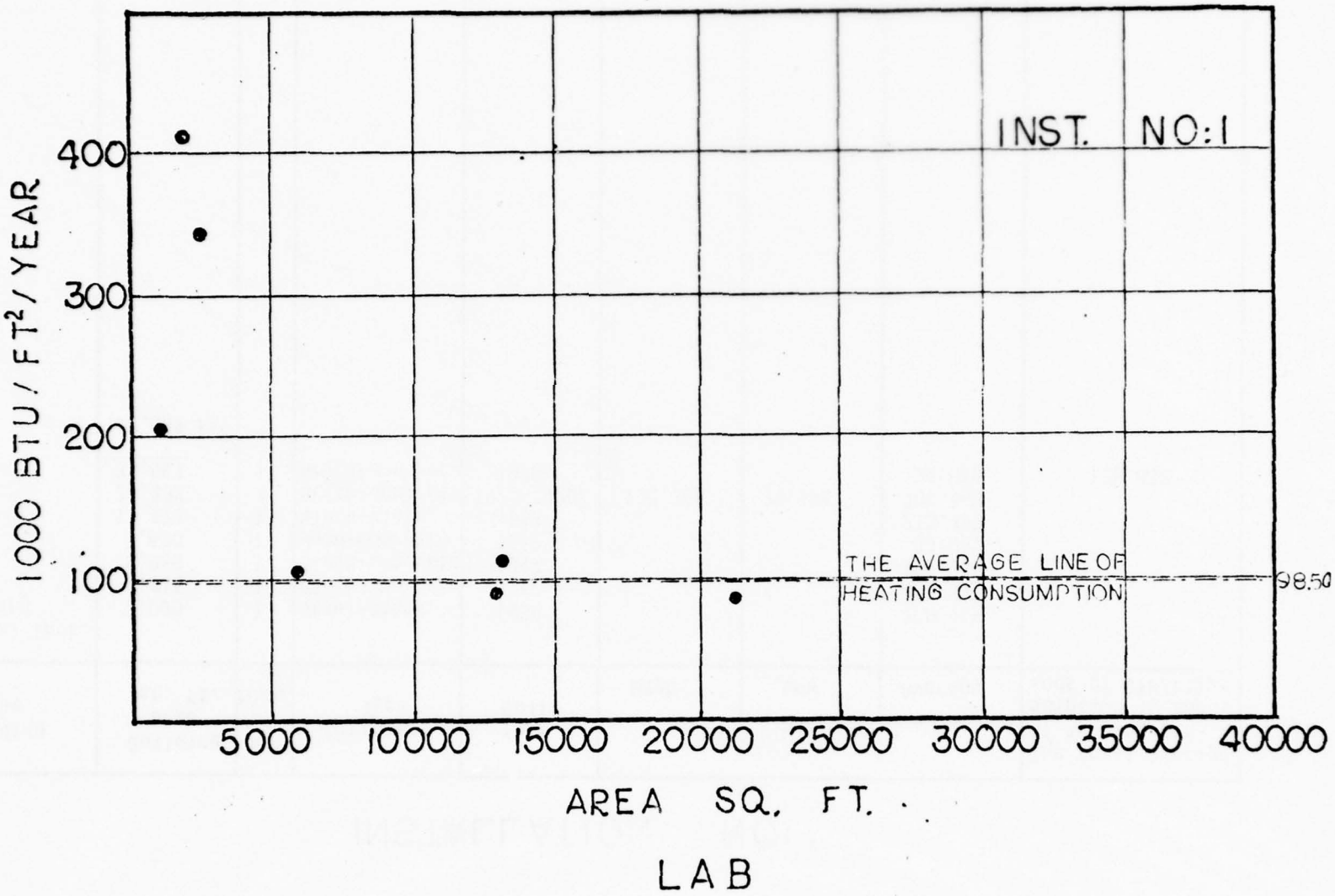
200
150
100
50
THE AVERAGE LINE OF
HEATING CONSUMPTION
177.758
INST. NO:1
2000
4000
6000
8000
10000
12000
AREA SQ. FT.
CHAPEL

INSTALLATION NO: 1

Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
Laboratory General Purposes	1,071	1	Concrete-glass	1963			206.928	
	1,830	1	Brick-concrete	1453			415.754	
	2,320	1	Brick-concrete	1963			344.840	
	5,856	1	Concrete	1965			103.290	
	12,925	1	Brick-concrete	1952			91.560	
	13,294	1	Brick-concrete	1957			113.651	
	21,565	1	Block-steel	1959			84.917	
	43,144	1	Block-concrete	1957			72.670	98.506
	102,005 ft^2							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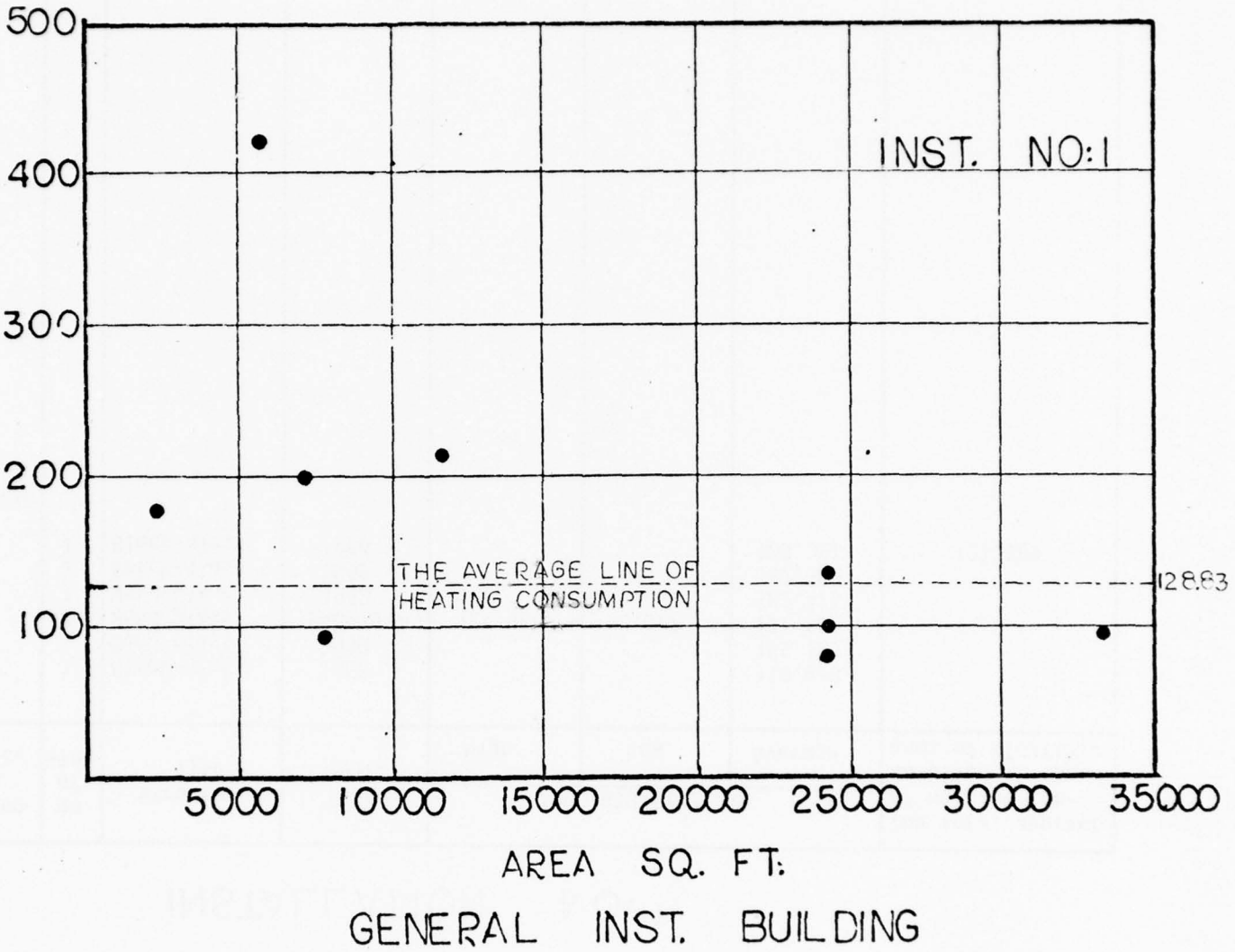
100
1000 BTU / FT² / YEAR
THE AVERAGE LINE OF
HEATING CONSUMPTION
98.50
5000
10000
15000
20000
25000
30000
35000
40000
AREA SQ. FT.

LAB

INSTALLATION NO: 1

Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
General Inst. Building	2,000	1	Steel-glass	1958			178.955	
	5,414	1	Block-concrete	1952			424.371	
	6,966	1	Block-concrete	1947			199.287	
	7,680	1	Wood-concrete	1942			93.023	
	11,474	1	Block-glass	1953			213.355	
	24,332	3	Brick-concrete	1928-1929	132.705	79.175	104.468	
	33,567	1	Brick-concrete	1928			95.866	128.838
	140,097 ft^2							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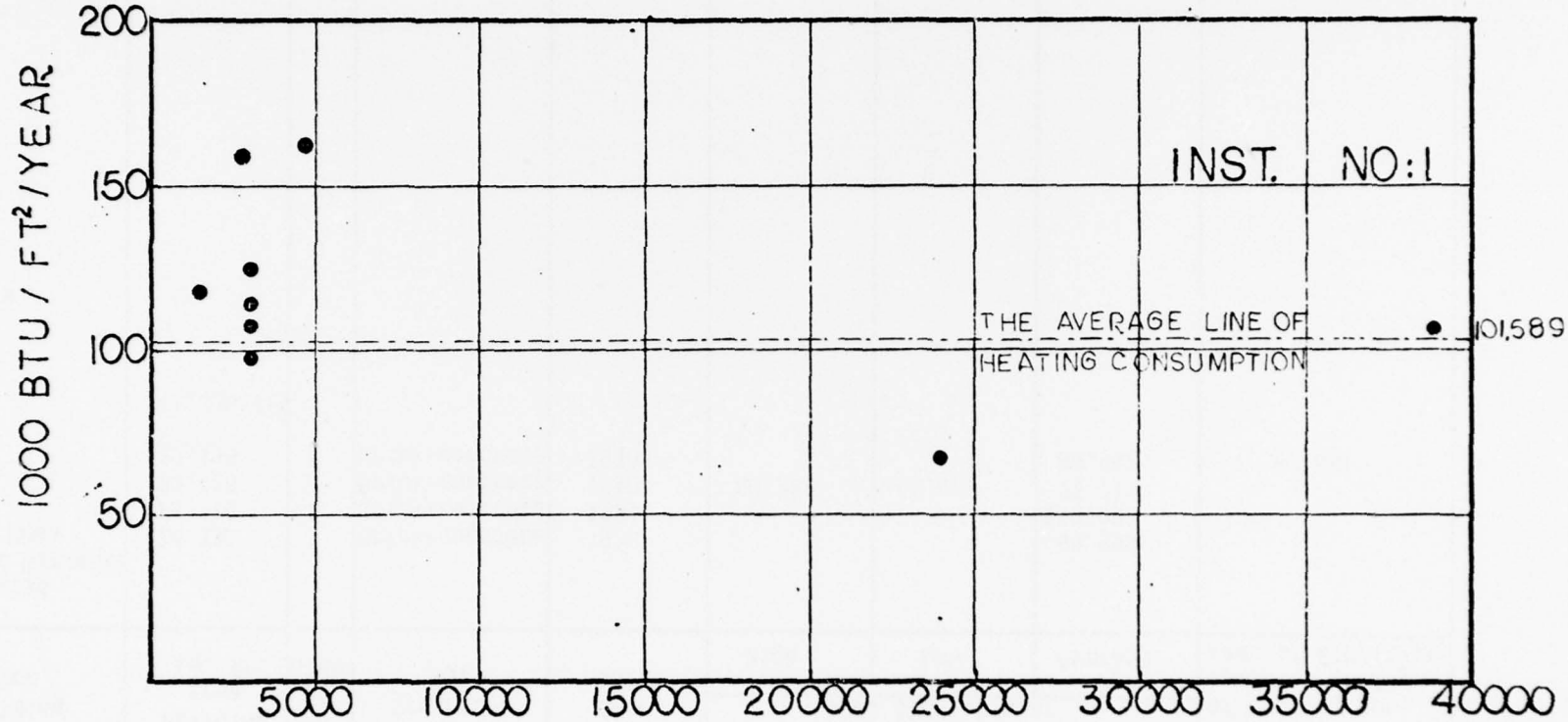
5000
10000
15000
20000
25000
30000
35000
AREA SQ. FT.
GENERAL INST. BUILDING

INSTALLATION NO: 1

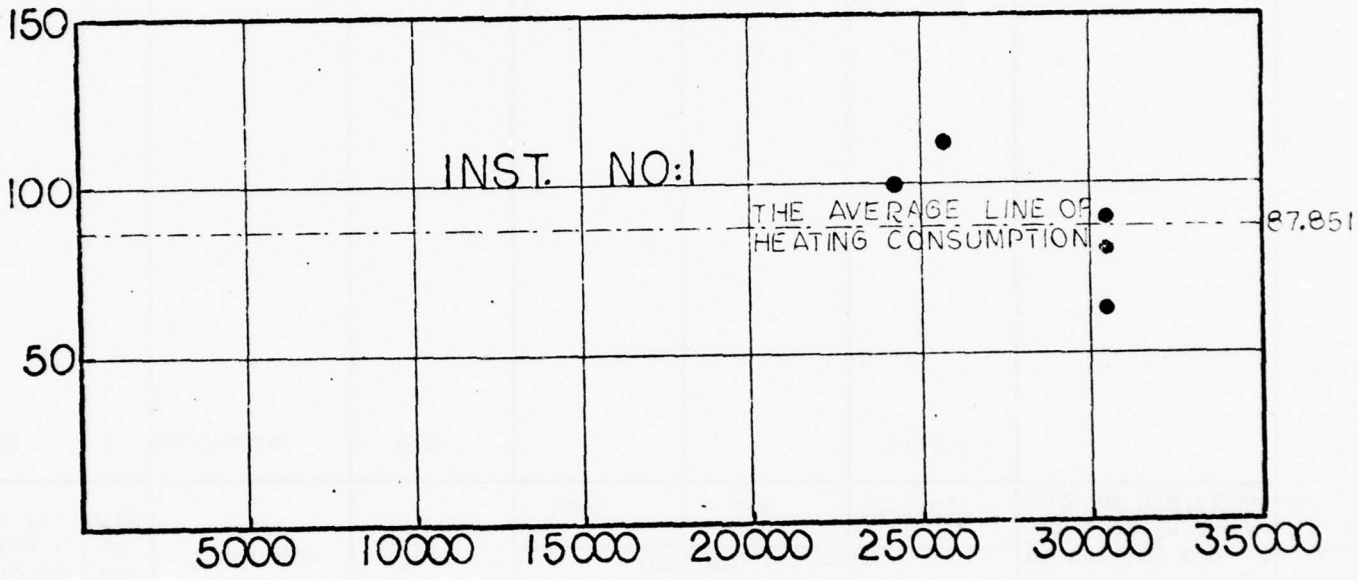
Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
Enlisted Men's Mess	1,230	1	Block-glass	1955			118.943	
	2,664	1	Wood-glass	1940			159.129	
	2,892	4	Wood-glass	1940-1941	126.058	98.077	111.662	
	4,428	1	Wood-glass	1942			163.475	
	24,045	1	Brick-glass	1965			67.568	
	38,949	1	Block-glass	1968			108.081	101.589
	82,884 ft^2							



ENLISTEDMEN MESS.

INSTALLATION NO: 1

Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
Enlisted Men's Barracks with Mess	24,332	1	Brick-concrete	1929			99.959	
	25,716	1	Brick-concrete	1934			112.082	
	30,426	2	Brick-concrete	1940	80.362	63.075	71.719	
	30,435	1	Brick-concrete	1940			89.952	87.851
	141,335 ft^2							



ENLISTEDMEN BKS WITH MESS

INSTALLATION NO: 1

Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
Post-Exchange	3,800	1	Wood-glass	1944			117.334	

INSTALLATION NO: 1

Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
EM Recreation Center	26,310	1	Concrete-concrete brick	1974			91.915	

INSTALLATION NO: 1

Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
Theater	15,552	1	Brick-concrete	1940			193.465	

INSTALLATION NO: 1

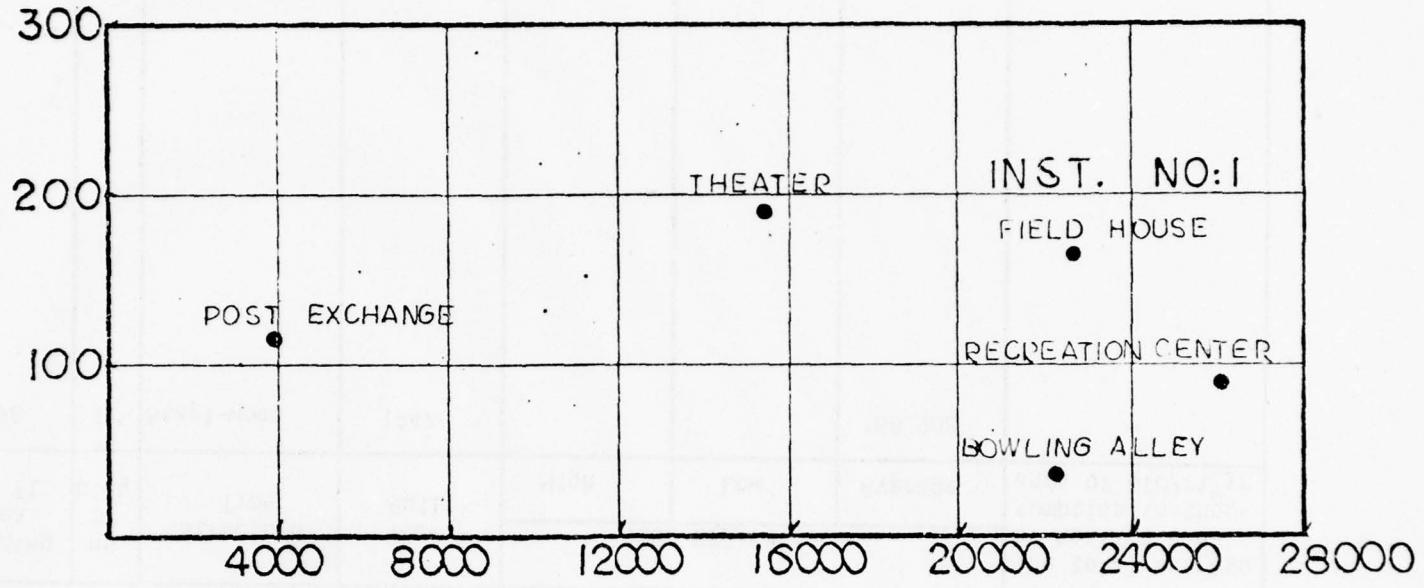
Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
Bowling Alley	22,400	1	Brick-glass	1965			36.321	

INSTALLATION NO: 1

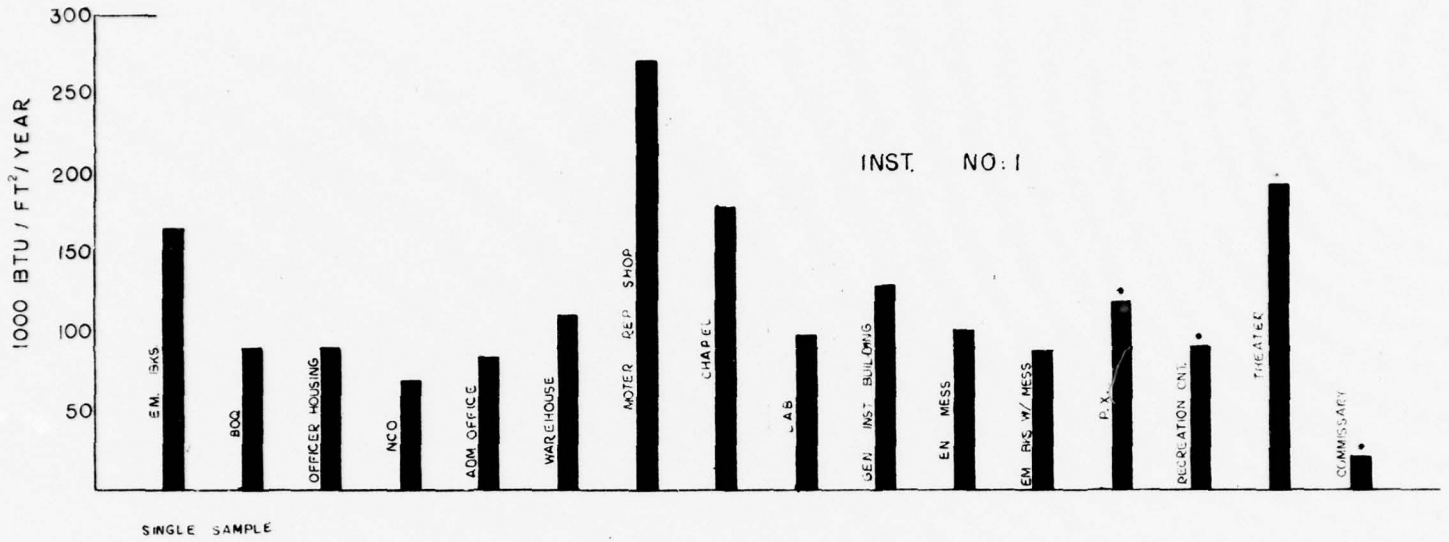
Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
Commissary	128,898	1	Brick-concrete	1974			19.008	

INSTALLATION NO: 1

Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
Field House	22,778	1	Steel-wood	1947			168.908	



DIFFERENT KINDS OF BUILDING

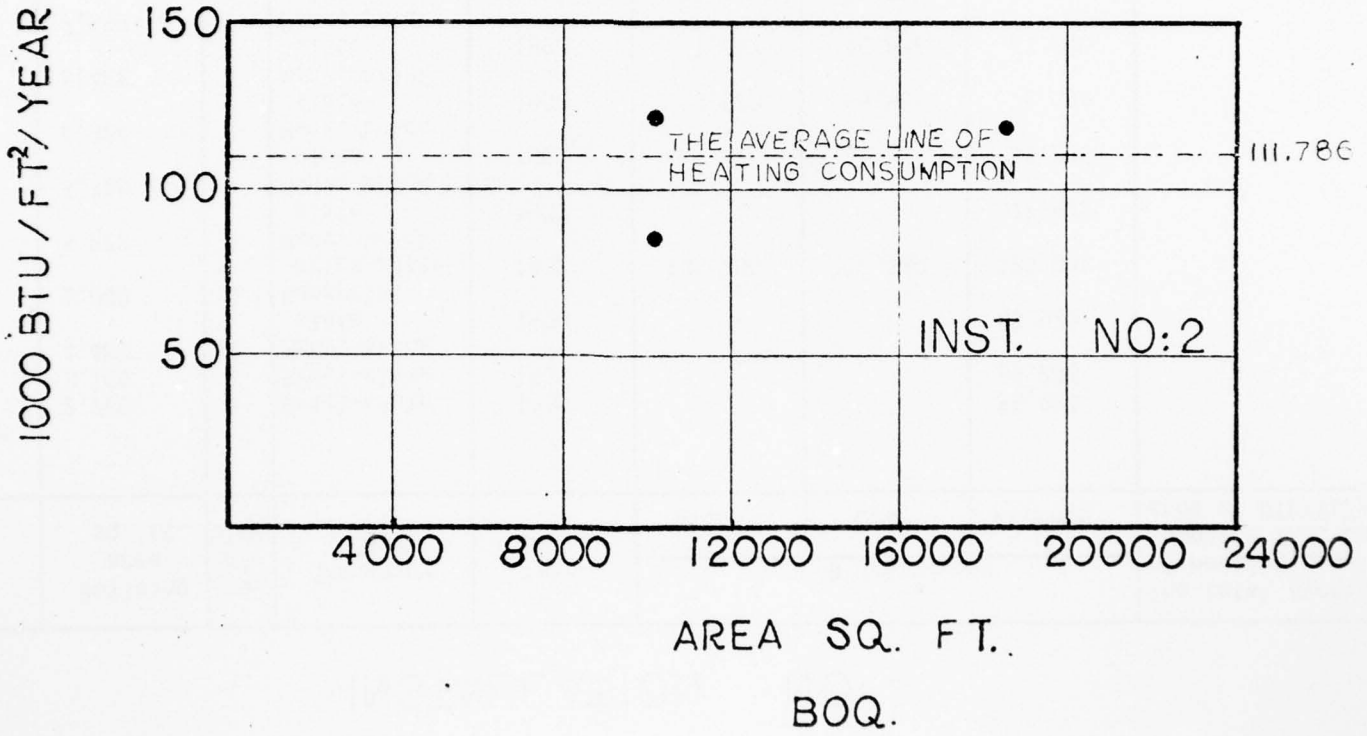

1000 BTU / FT² / YEAR
300
250
200
150
100
50
INST. NO: 1
E.M. BKS
BOQ
OFFICER HOUSING
NCO
ADM OFFICE
WAREHOUSE
MOTER REP SHOP
CHAPEL
LAB
GEN. INST. BUILDING
EN MESS
EM BKS. W/ MESS
P.X.
RECREATION CNT.
THEATER
COMMISSARY
SINGLE SAMPLE

APPENDIX B

INSTALLATION NO. 2

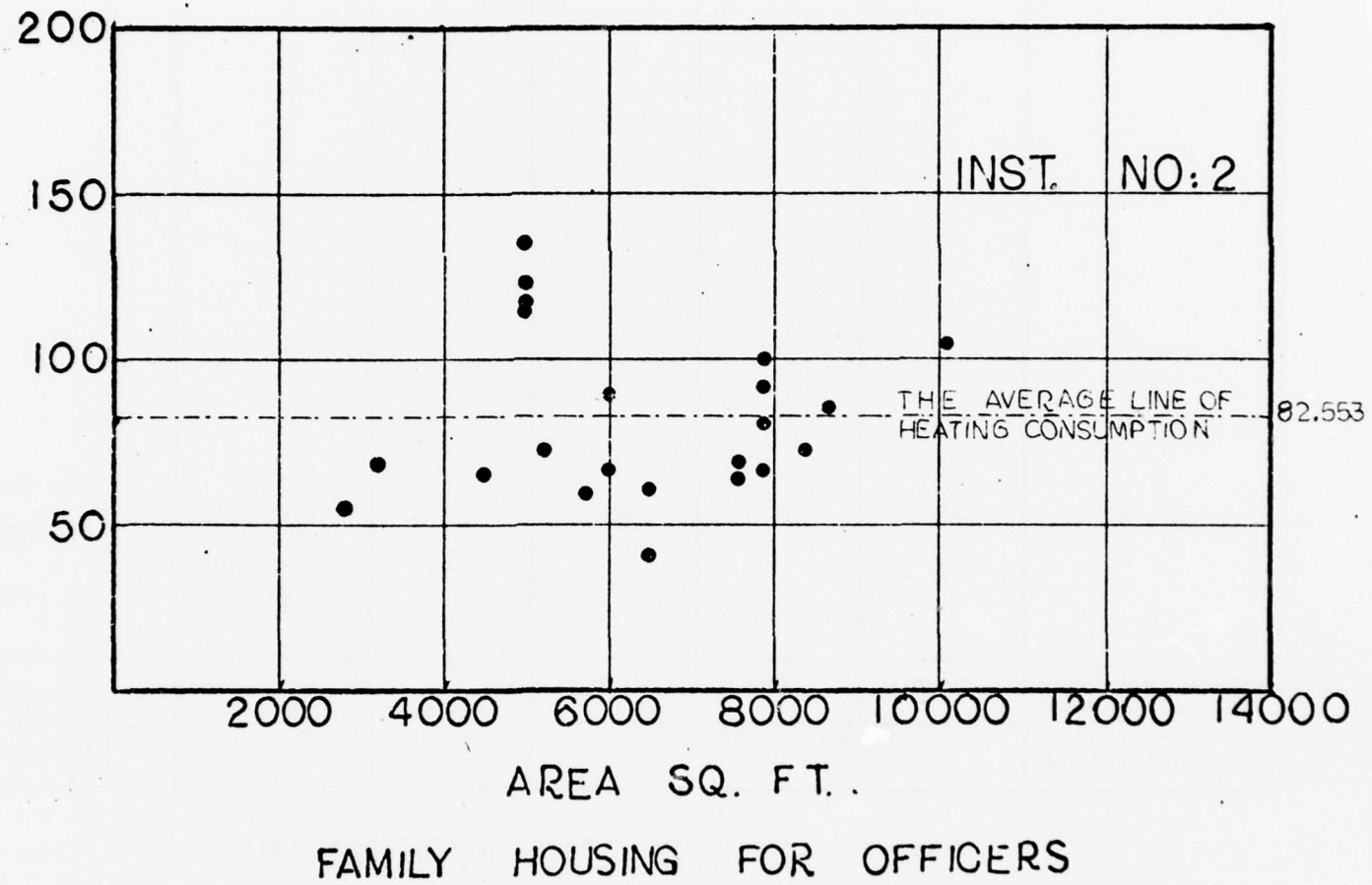
INSTALLATION NO: 2

Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
BOQ	10,238	2	Concrete, wood, As	1940-1944	123.645	86.539	105.092	
	18,626	1	Concrete, brick, slate	1906			119.146	111.786
	39,102 ft^2							


1000 BTU / FT² / YEAR
150
100
50
THE AVERAGE LINE OF HEATING CONSUMPTION
111.786
INST. NO:2
4000
8000
12000
16000
20000
24000
AREA SQ. FT.
BOQ.

INSTALLATION NO: 2

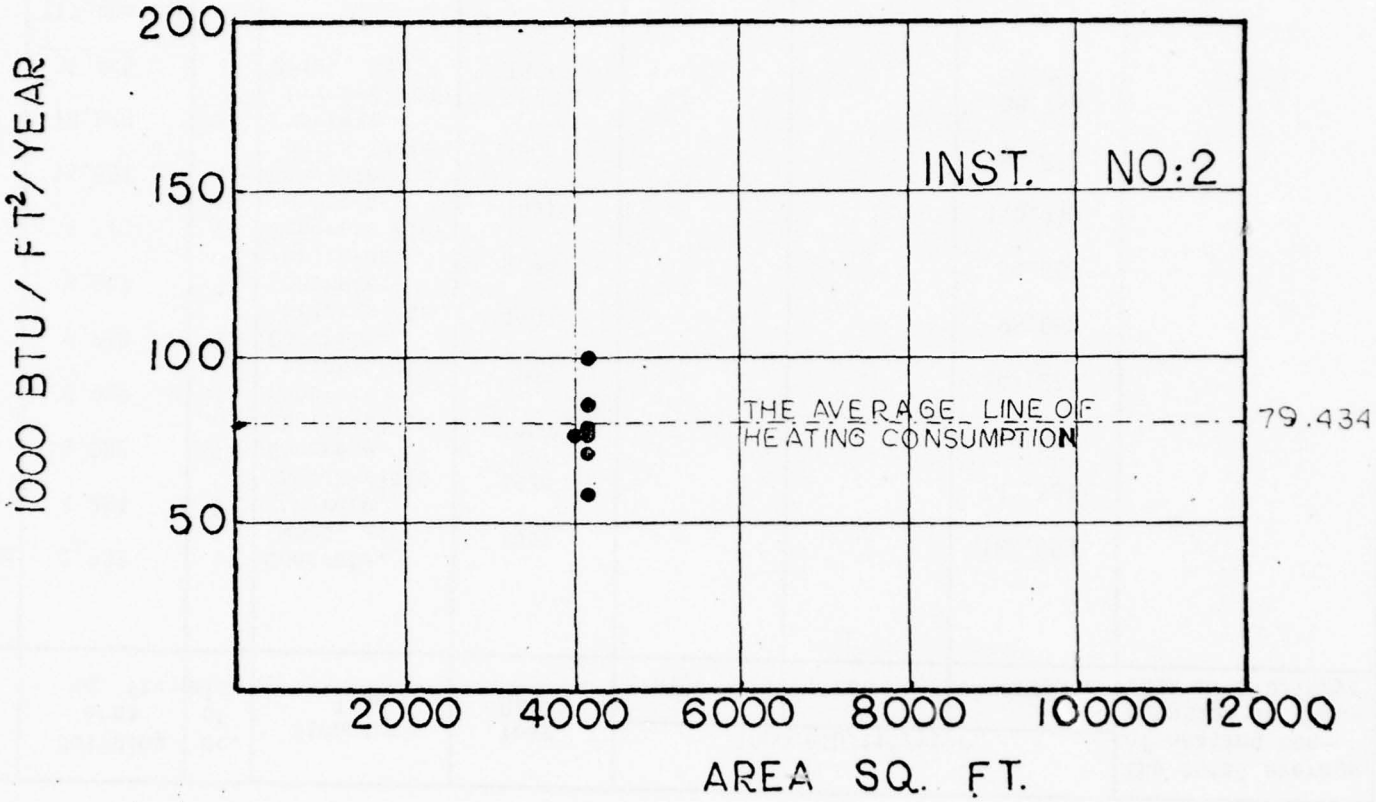
Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
Family Housing for Officers	2,765	1	Brick-slate	1935			55.924	
	3,165	1	Brick-slate	1935			69.248	
	4,481	1	Msny, brick slate	1903			65.923	
	5,040	4	Concrete, brick-slate	1932	135.458	116.139	123.007	
	5,222	1	Msny, brick slate	1903			72.922	
	5,748	1	Msny, brick slate	1899			59.295	
	6,024	2	Msny, brick slate	1903	89.522	66.665	78.094	
	6,488	2	Msny, brick slate	1892	61.843	40.836	51.340	
	7,588	2	Msny, brick slate	1908	68 469	65.507	66.988	
	7,890	4	Msny, brick slate	1896	100.005	66.274	84.530	
	8,400	1	Stone, brick slate	1903			73.567	
	8,675	1	Msny, brick slate	1908			86.033	
	10,111	1	Msny, brick	1899			105.952	82,553
	140,487 ft^2							



FAMILY HOUSING FOR OFFICERS

INSTALLATION NO: 2

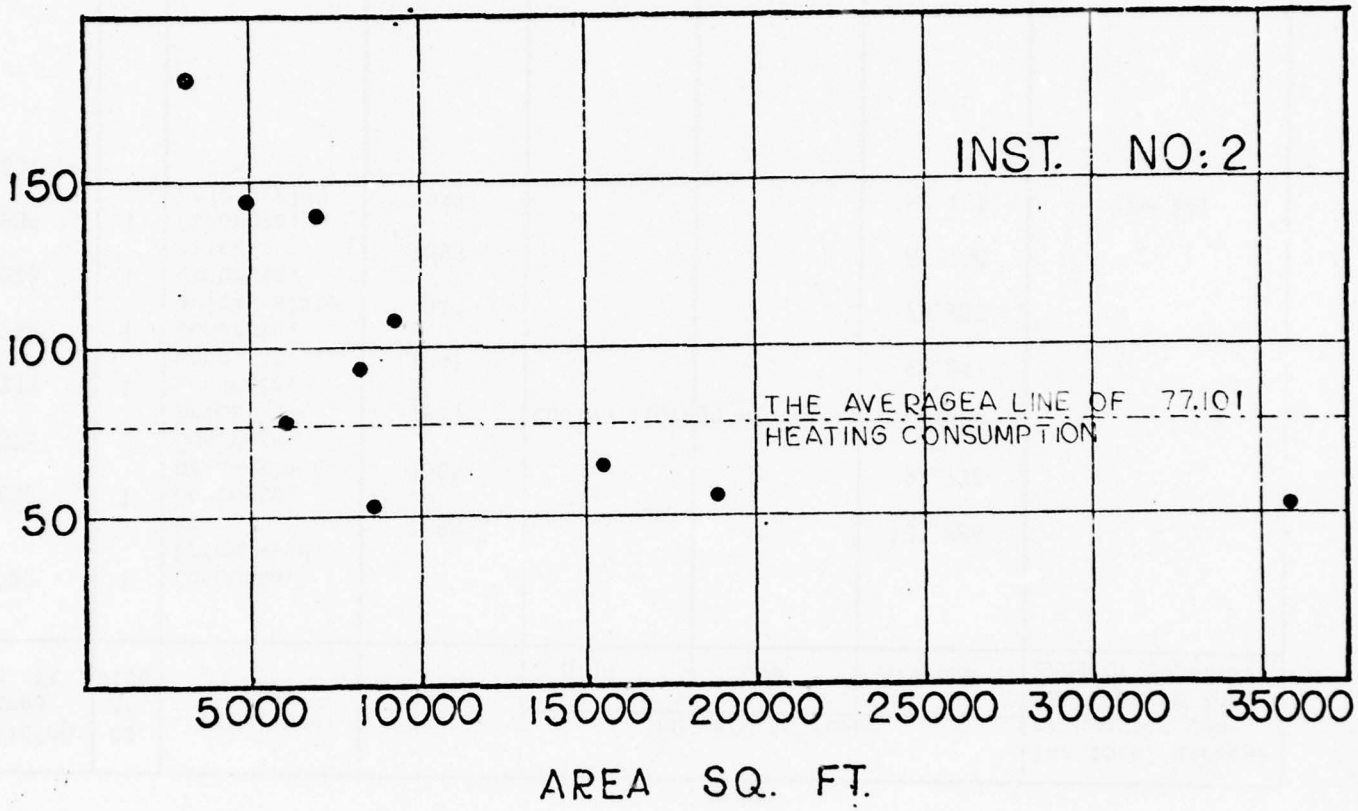
Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
NCO Family Housing	4,091	1	Concrete, brick-slate	1934			77.854	
	4,184	6	Concrete, brick-slate	1932	99.880	60.798	79.692	79.434
	29,195 ft^2							



NCO FAMILY HOUSING

INSTALLATION NO: 2

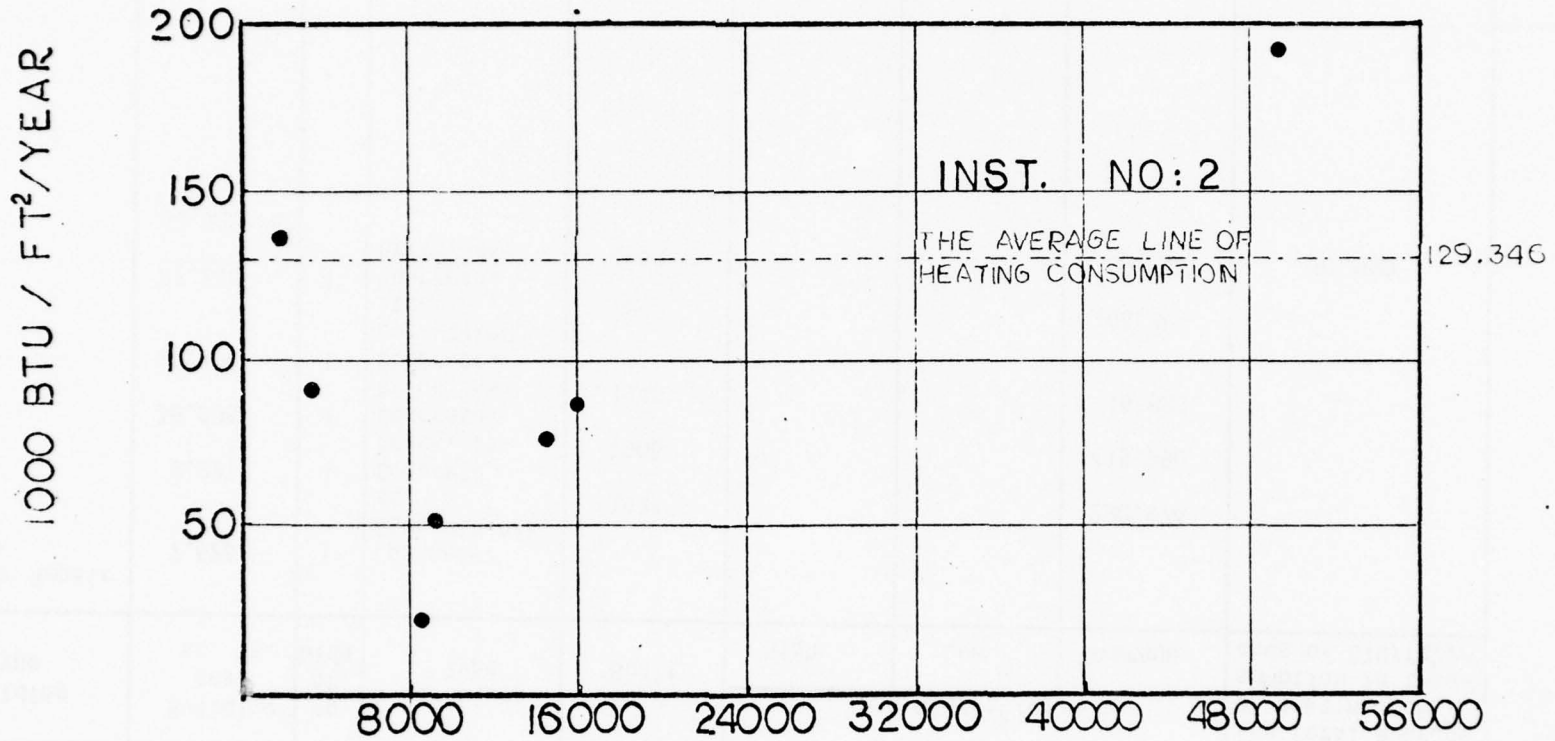
Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
Administration General Purp. Offices	2,933	1	Concrete, wood, as	1941			182.053	
	4,864	1	Concrete, brick-slate	1934			146.534	
	6,082	1	Concrete, brick-slate	1900			80.335	
	6,980	1	Concrete, brick-slate	1895			141.223	
	8,250	1	Concrete, brick-slate	1900			95.658	
	8,607	1	Concrete, brick-as	1899			54.360	
	9,210	1	Concrete Piers wood, as	1941			110.449	
	15,501	1	Concrete, brick-slate	1900			66.812	
	18,888	1	Concrete, brick-slate	1899			58.793	
	35,969	1	Brick, as	1896			52.857	77.101
	117,284 ft^2							



ADMINISTRATION GENERAL PURP. OFFICES

INSTALLATION NO: 2

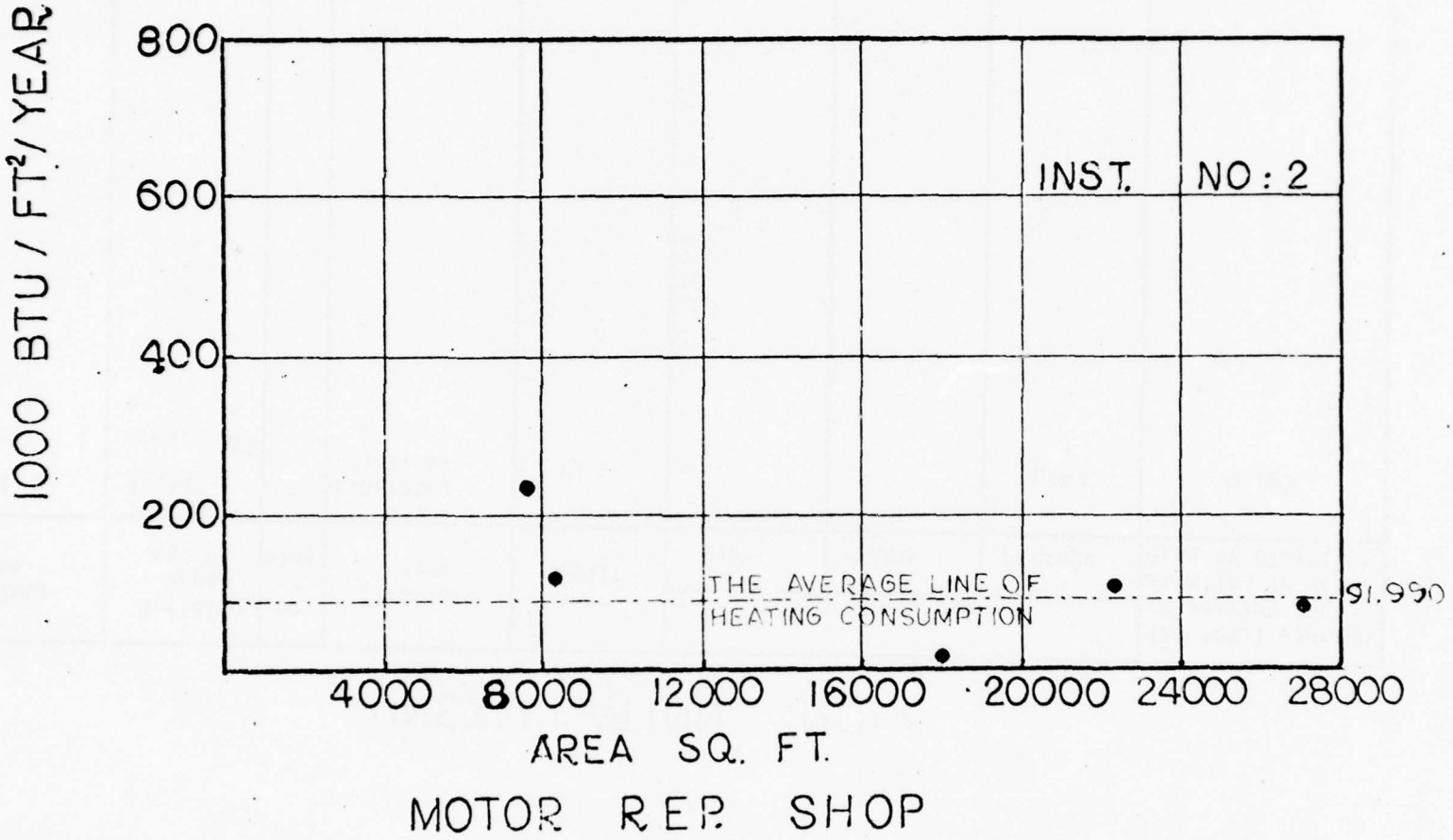
Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
General Purp. Warehouse	1,722	1	Concrete, brick, wood, as	1896			137.886	
	3,230	1	Concrete, brick-slate	1905			92.712	
	8,375	1	Concrete, brick, as	1926	Cooled storage wrhse.		22.801	
	9,333	1	Concrete, wood, as	1941			52.247	
	14,232	1	Concrete, brick, slate	1943			78.263	
	16,023	1	Concrete, brick	1893			87.156	
	49,686	1	Concrete, brick, slag	1939			192.111	129.346
	102,601 ft^2							


200
150
100
50
1000 BTU / FT²/YEAR
INST. NO: 2
THE AVERAGE LINE OF
HEATING CONSUMPTION
129.346
8000
16000
24000
32000
40000
48000
56000
AREA SQ. FT.

WAREHOUSE

INSTALLATION NO: 2

Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
Motor Repair Shop	7,626	1	Concrete, Concrete blk, as	1934			230.974	
	8,221	1	Concrete, brick, as	1906			119.990	
	18,095	1	Concrete, brick, as	1940			16.820	
	22,400	1	Concrete, corrugated steel	1940			106.359	
	27,240	1	Concrete, brick, as	1919			82.748	91.990
	83,582 ft^2							


1000 BTU / FT² / YEAR
800
600
400
200
INST. NO: 2
THE AVERAGE LINE OF HEATING CONSUMPTION
91.990
4000
8000
12000
16000
20000
24000
28000
AREA SQ. FT.
MOTOR REP. SHOP

INSTALLATION NO: 2

Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
Chapel	10,127 10,127 ft^2	1	Concrete, brick, as	1935			78.087	78.087

INSTALLATION NO: 2

Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
Officer's Mess	65,000	1	Concrete, brick-slate	1896			102.006	

INSTALLATION NO: 2

Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
EM Mess	8,080	1	Concrete, wood, as	1918			58.486	

INSTALLATION NO: 2

Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
EM Barracks with Mess	20,081	1	Concrete, brick, slate	1915			93.373	

INSTALLATION NO: 2

Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
Gymnasium	24,877	1	Concrete, brick, slate	1934			212.527	

INSTALLATION NO: 2

Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
Post Exchange	17,562	1	Concrete, brick, slate	1904			57.345	

INSTALLATION NO: 2

Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
Theater	4,851	1	Concrete, brick, as	1929			274.733	

INSTALLATION NO: 2

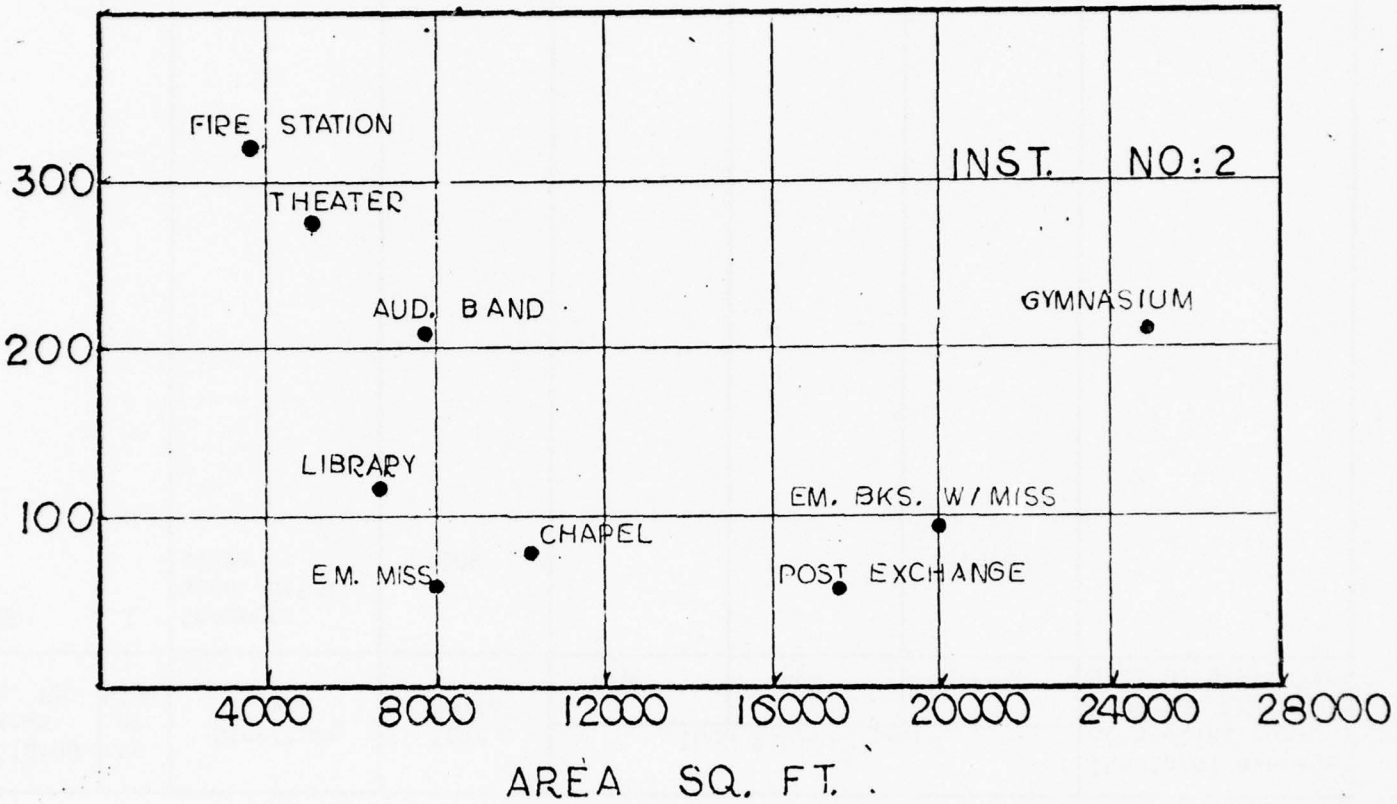
Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
Library	6,464	1	Concrete, asbestos shingle, as	1929			117.064	

INSTALLATION NO: 2

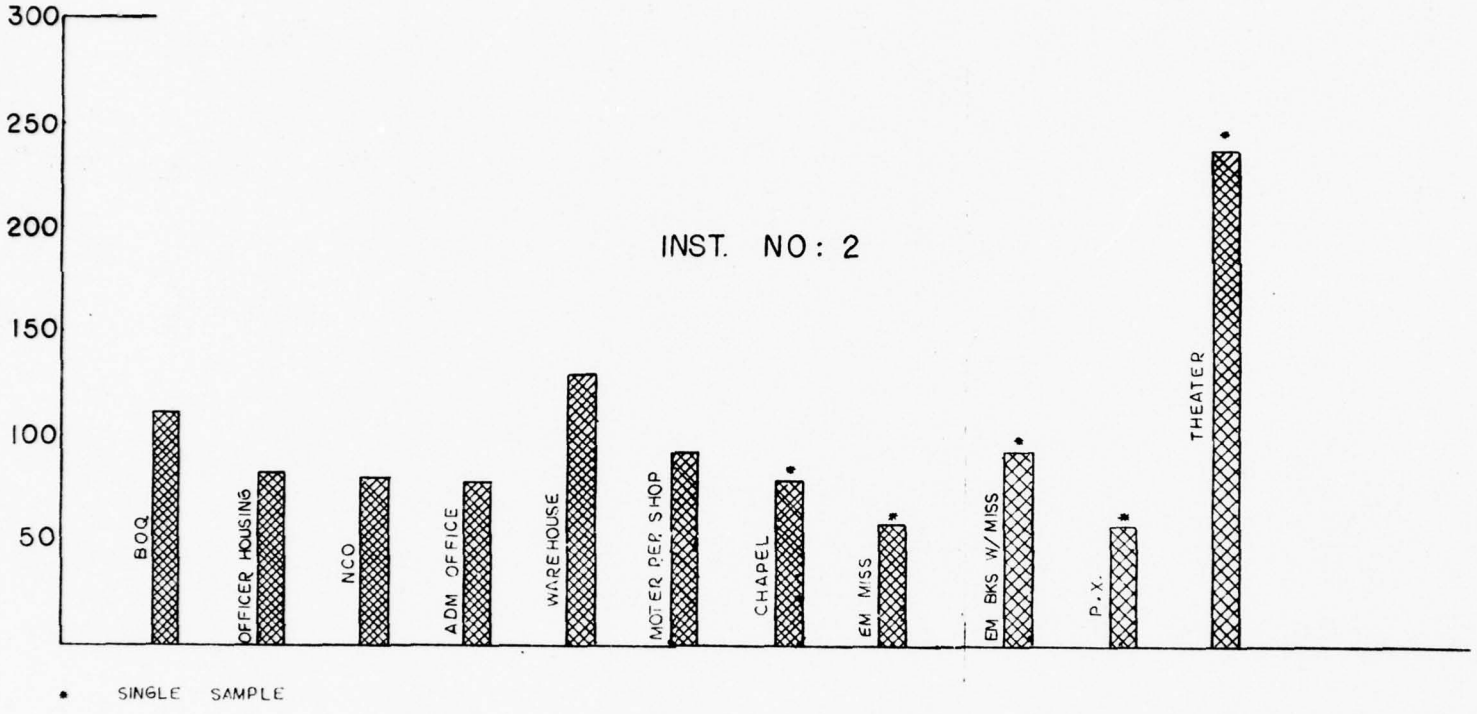
Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
Aud, Band	7,661	1	Concrete, wood, as	1942			209.854	

INSTALLATION NO: 2

Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
Fire Station	3,588	1	Concrete, wood, brick slate	1909			322,687	



DIFFERENT KINDS OF BUILDING

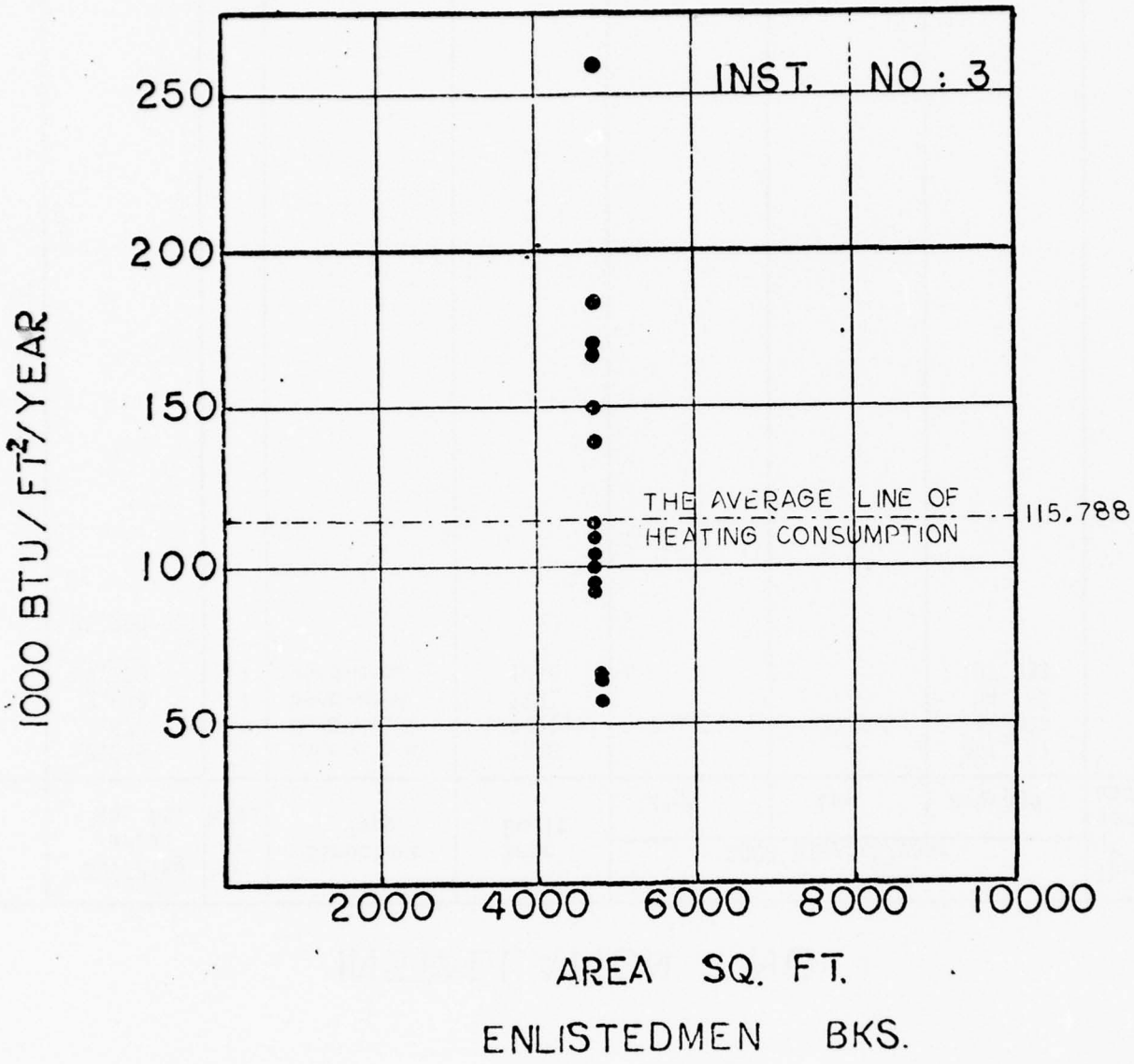

300
250
200
150
100
50
INST. NO: 2
BOQ
OFFICER HOUSING
NCO
ADM OFFICE
WAREHOUSE
MOTER PER SHOP
CHAPEL
EM MESS
EM BKS W/MESS
P.X.
THEATER
• SINGLE SAMPLE

APPENDIX C

INSTALLATION NO. 3

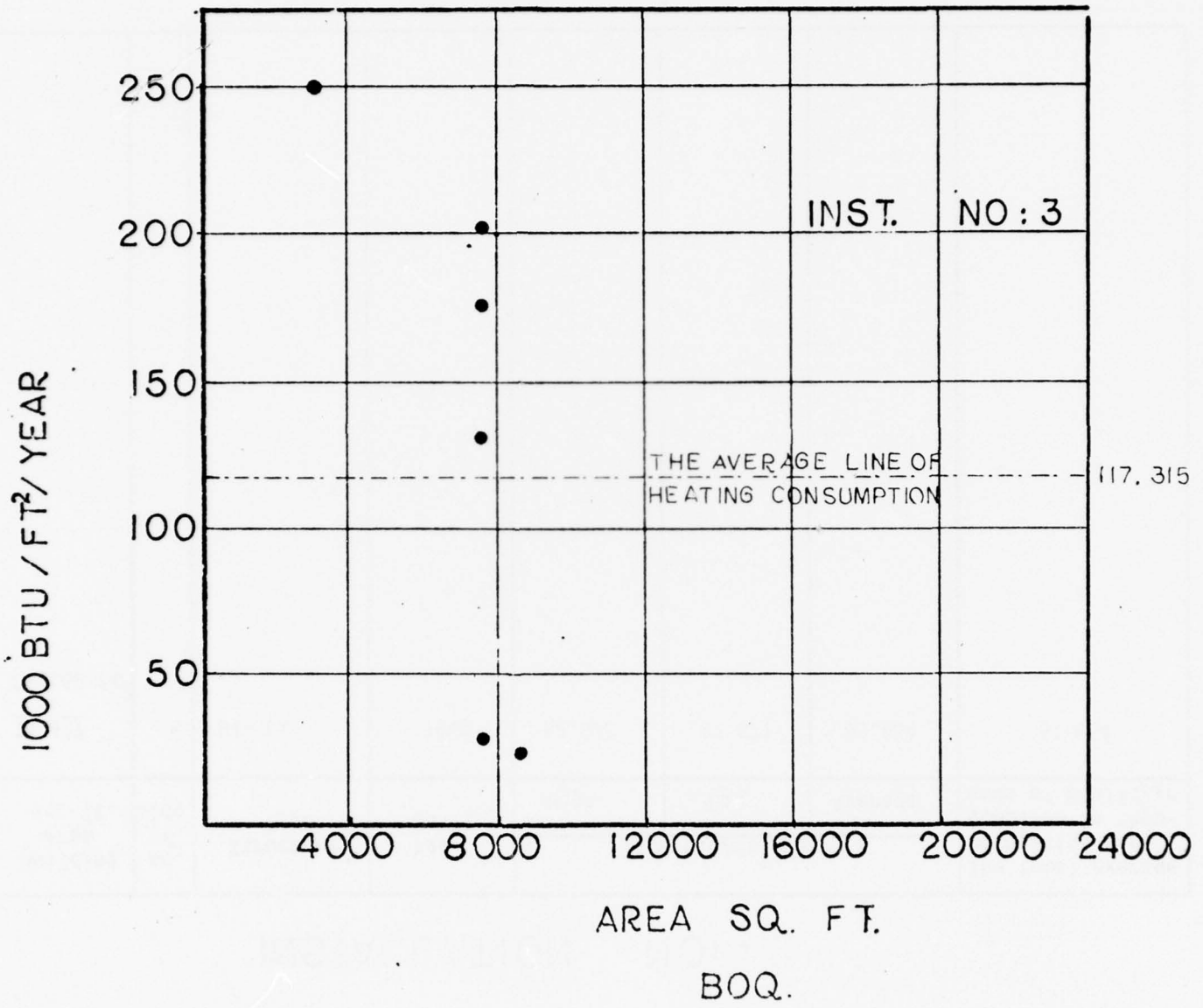
INSTALLATION NO: 3

Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
EM Barracks	4,720	20	Wood-wood	1941	260.676	57.038	109.627	115.788
	5,310	2	Wood-wood	1942	172.429	168.791	170.61	
	105,020 ft^2							


INST. NO : 3
250
200
150
100
50
THE AVERAGE LINE OF
HEATING CONSUMPTION
115.788
1000 BTU / FT² / YEAR
2000
4000
6000
8000
10000
AREA SQ. FT.
ENLISTEDMEN BKS.

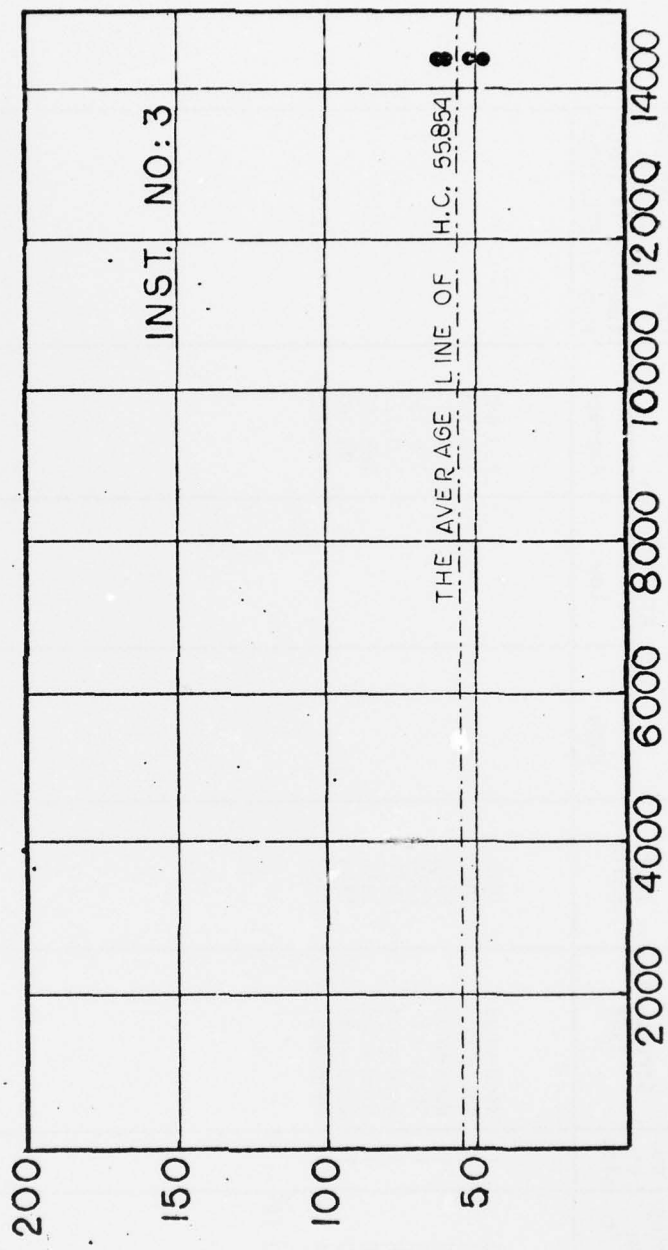
INSTALLATION NO: 3

Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
BOQ	3,016	1	Concrete-bk	1938			251.127	
	7,670	5	Wood-wood	1941-1942	203.392	30.519	135.882	
	8,614	1	Wood-wood	1941			24.558	
	31,720	1	Wood-wood	1952			107.333	117.315
	81,700 ft^2							


250
200
150
100
50
INST. NO: 3
THE AVERAGE LINE OF
HEATING CONSUMPTION
117. 315
1000 BTU / FT² / YEAR
4000
8000
12000
16000
20000
24000
AREA SQ. FT.
BOQ.

INSTALLATION NO: 3

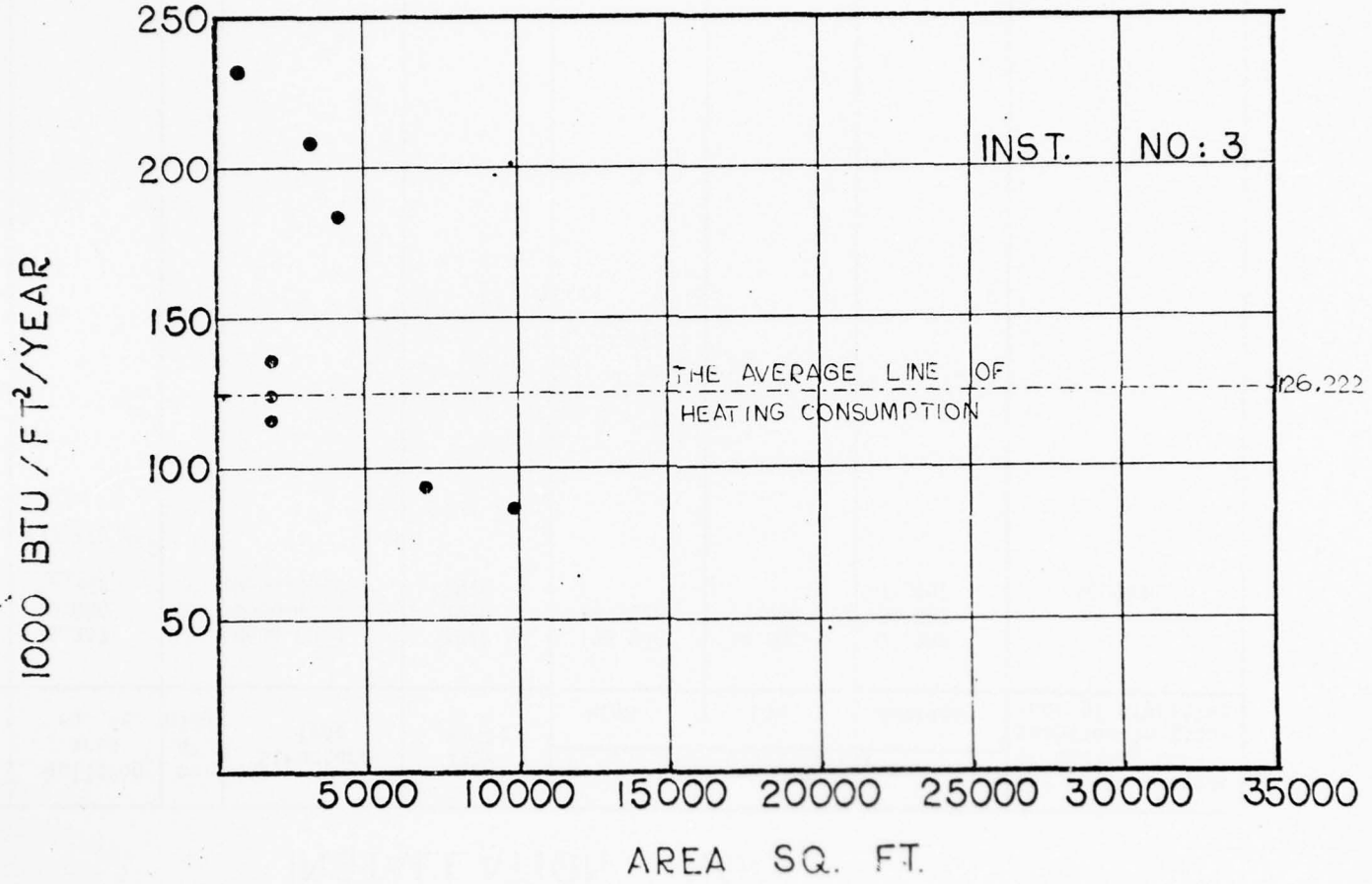
Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
NCO Family Housing	14,427 86,562 ft^2	6	Blk-bk	1950	62.872	47.671	55.854	55.854



NCO FAMILY HOUSING

INSTALLATION NO: 3

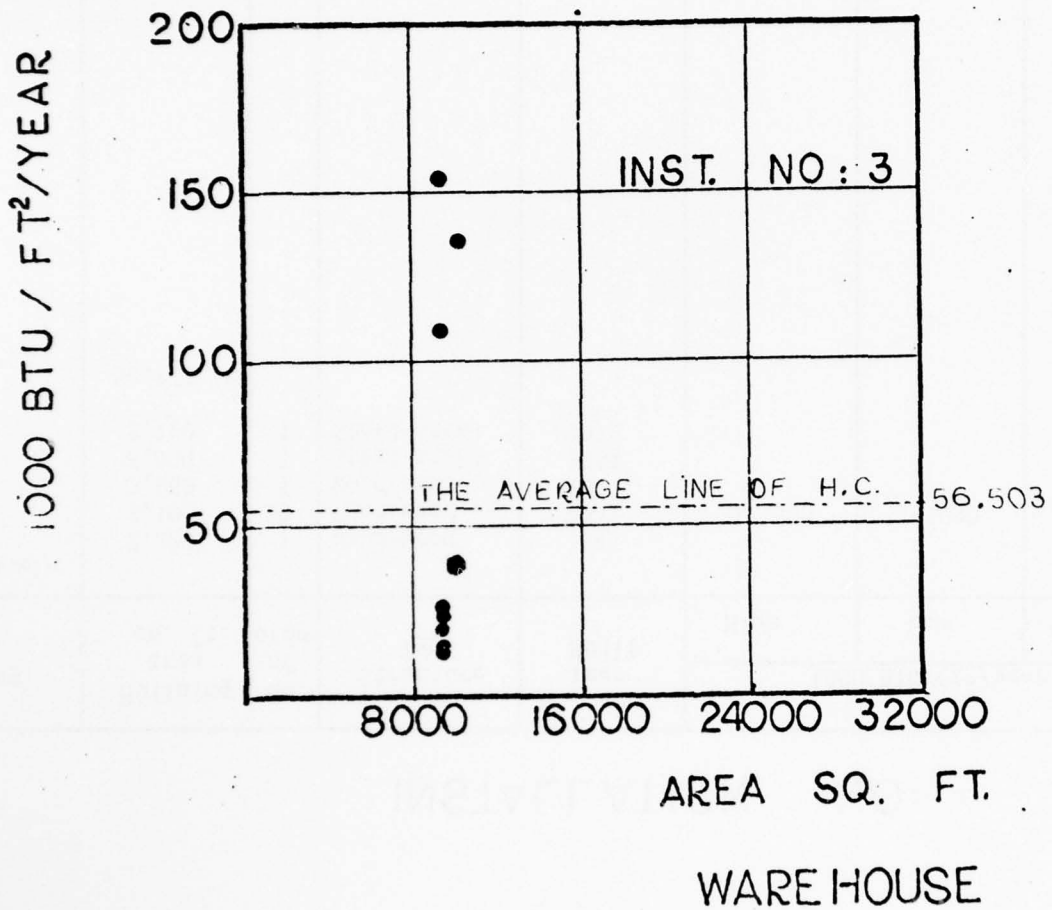
Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
Administration General Purp. Offices	736	1	Wood-wood	1942			233.492	
	1,814	1	Blk-blk	1960			125.375	
	1,828	1	Wood-wood	1942			117.713	
	1,920	1	Steel-st	1959			138.155	
	3,108	1	Wood-wood	1941			210,721	
	4,130	1	Wood-wood	1941			185.898	
	7,060	1	Wood-wood	1943			94.163	
	9,804	1	Wood-wood	1942			88.735	126.222
	30,400 ft^2							



ADMINISTRATION GENERAL PURP. OFFICES

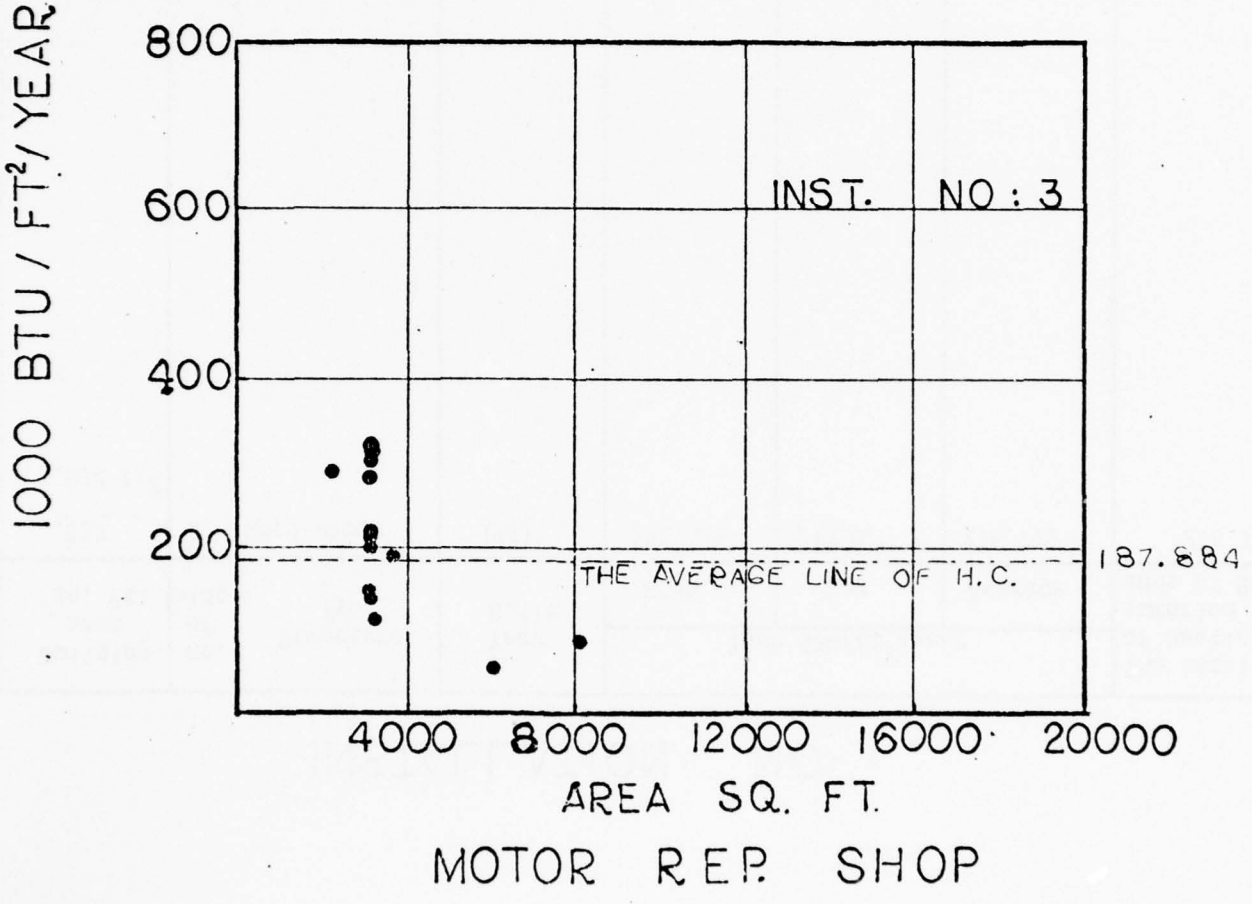
INSTALLATION NO: 3

Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
General Purp Warehouse	9,267	10	Wood-wood	1941	155.946	14.896	57.389	
	10,080	3	Wood-wood	1918	137.326	13.486	58.965	
	10,368	1	Wood-wood	1918			41.407	56.503
	133,278 ft^2							


200
150
100
50
INST. NO : 3
THE AVERAGE LINE OF H.C.
56.503
1000 BTU / FT²/YEAR
8000
16000
24000
32000
AREA SQ. FT.
WAREHOUSE

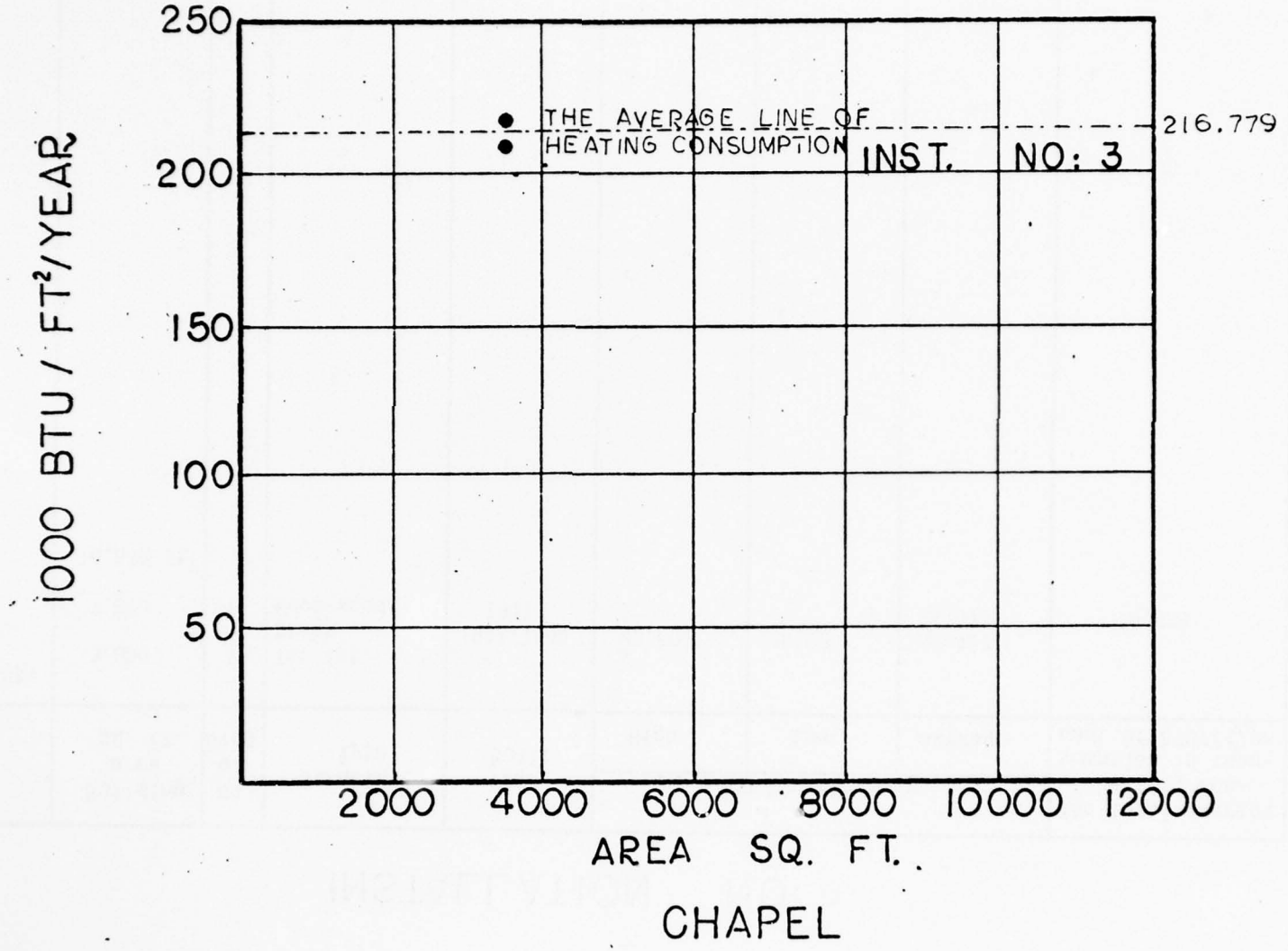
INSTALLATION NO: 3

Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
Motor Repair Shop	2,220	1	Wood-wood	1941			288.072	
	3,108	10	Wood-wood	1941	317.500	115.090	229.376	
	3,558	1	Wood-wood	1941			191.074	
	6,000	1	Steel-steel	1964			60.620	
	8,120	1	Steel-steel	1970			94.319	187.884
	50,978 ft^2							


1000 BTU / FT² / YEAR
800
600
400
200
INST. NO : 3
THE AVERAGE LINE OF H.C.
187.684
4000
8000
12000
16000
20000
AREA SQ. FT.
MOTOR REP. SHOP

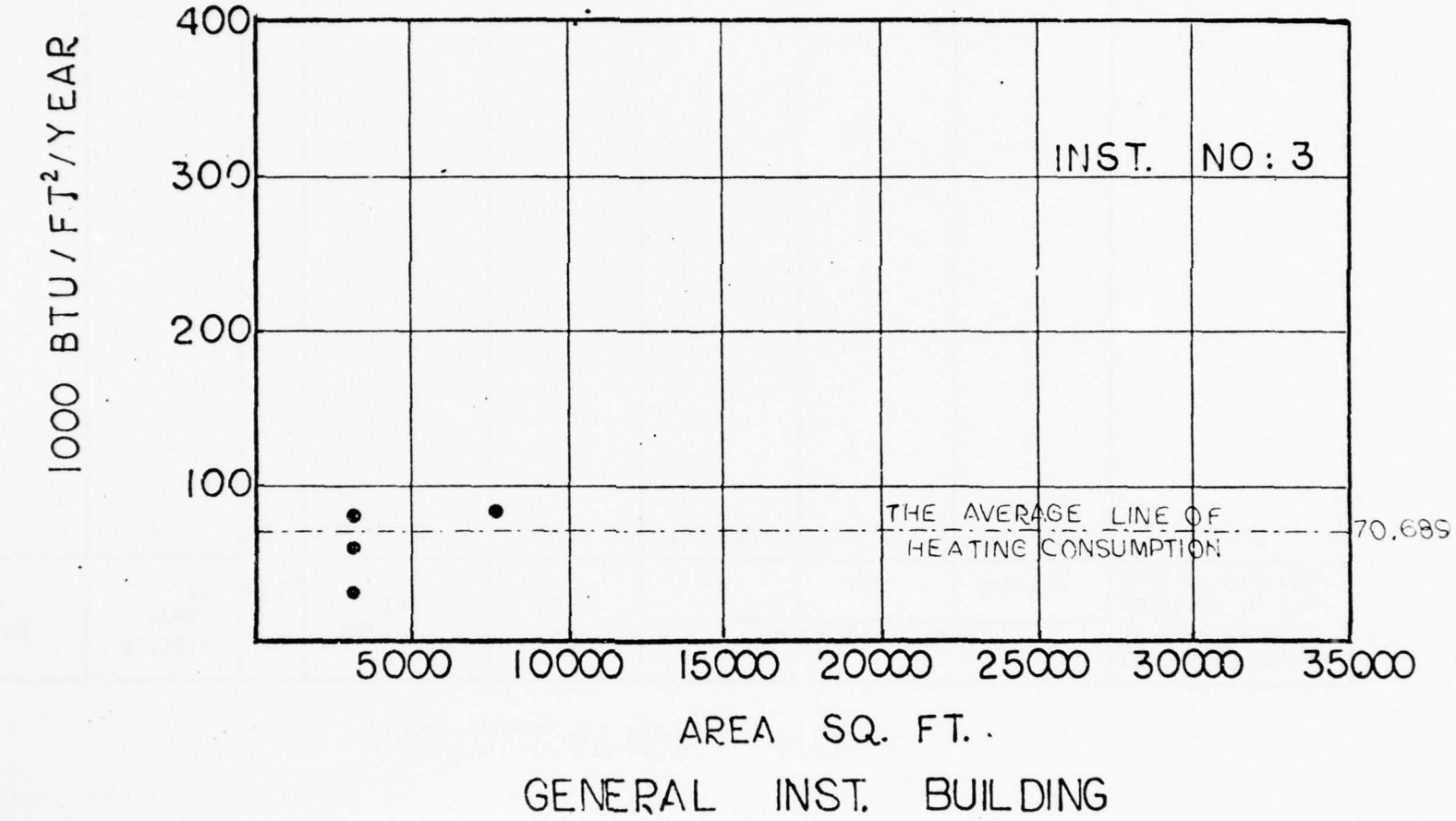
INSTALLATION NO: 3

Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
Chapel	3,537 7,074 ft^2	2	Wood-wood	1941	220.529	213.028	216.779	216.779


250
200
150
100
50
1000 BTU / FT²/YEAR
THE AVERAGE LINE OF
HEATING CONSUMPTION
INST. NO: 3
216.779
2000
4000
6000
8000
10000
12000
AREA SQ. FT.
CHAPEL

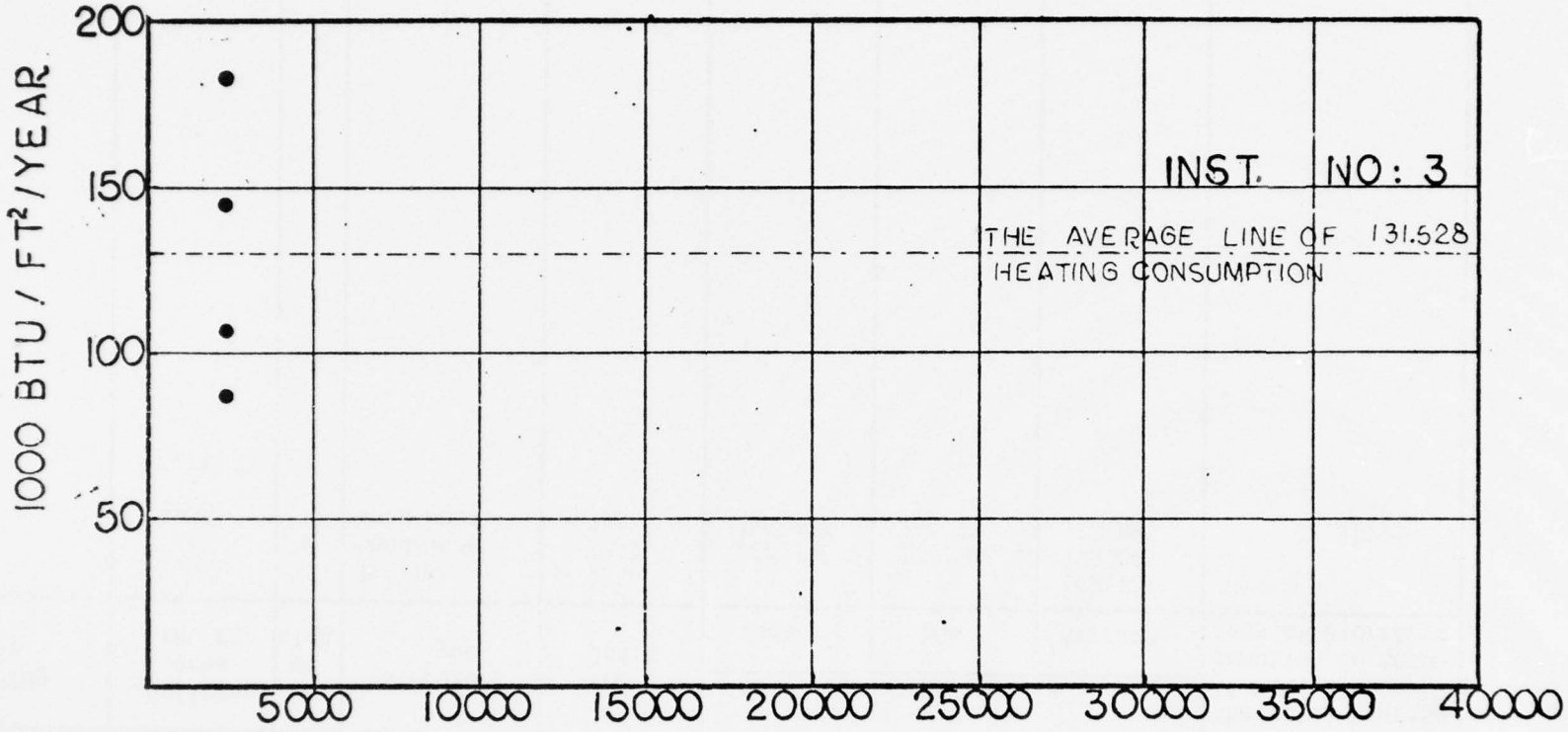
INSTALLATION NO: 3

Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
General Inst. Building	3,000	3	Tst-tst, bk-bk	1941-1944	83.603	30.03	58.427	
	7,670	1	Wood-wood	1941			85.077	70.689
	16,670 ft^2							


1000 BTU / FT² / YEAR
400
300
200
100
INST. NO: 3
THE AVERAGE LINE OF
HEATING CONSUMPTION
70.685
5000
10000
15000
20000
25000
30000
35000
AREA SQ. FT.
GENERAL INST. BUILDING

INSTALLATION NO: 3

Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
En-Men's Mess	2,208 8,832 ft^2	4	Wood-wood	1941	185.272	87.437	131.528	131.528



ENLISTEDMEN MESS.

INSTALLATION NO: 3

Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
P.X.	2,200	1	Tst-tst	1932			147.127	
	2,331	2	Wood-wood	1941	202.282	147.808	175.045	
	3,663	2	Wood-wood	1941	183.227	134.535	158.881	162.370
	14,188 ft^2							

AD-A048 324 ARMY FACILITIES ENGINEERING SUPPORT AGENCY FORT BELV--ETC F/G 13/1
BUILDING HEATING ENERGY CONSUMPTION AT FIXED FACILITIES.(U)
JUN 77 M M BOTROS

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2 OF 2
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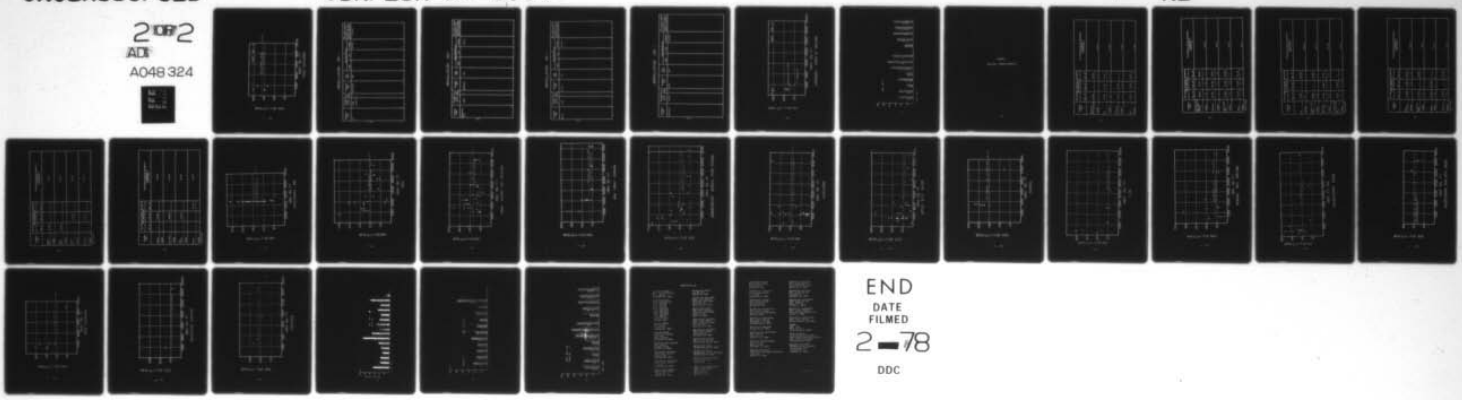

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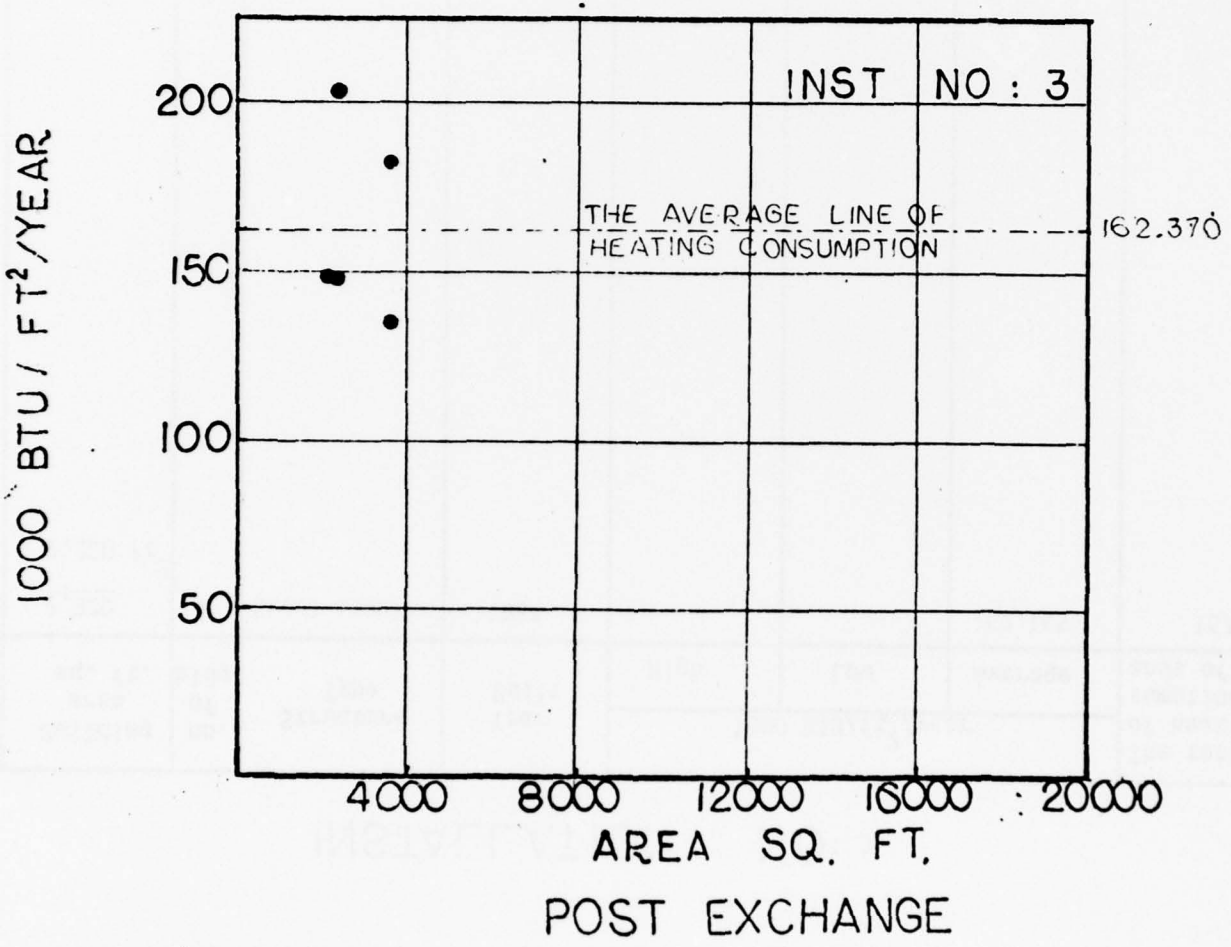

INST NO : 3
200
150
100
50
THE AVERAGE LINE OF HEATING CONSUMPTION
162.370
1000 BTU / FT² / YEAR
4000
8000
12000
16000
20000
AREA SQ. FT.
POST EXCHANGE

INSTALLATION NO: 3

Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
Lab	2,320 2,320 ft^2	1	Steel-steel	1964			167.155	167.155

INSTALLATION NO: 3

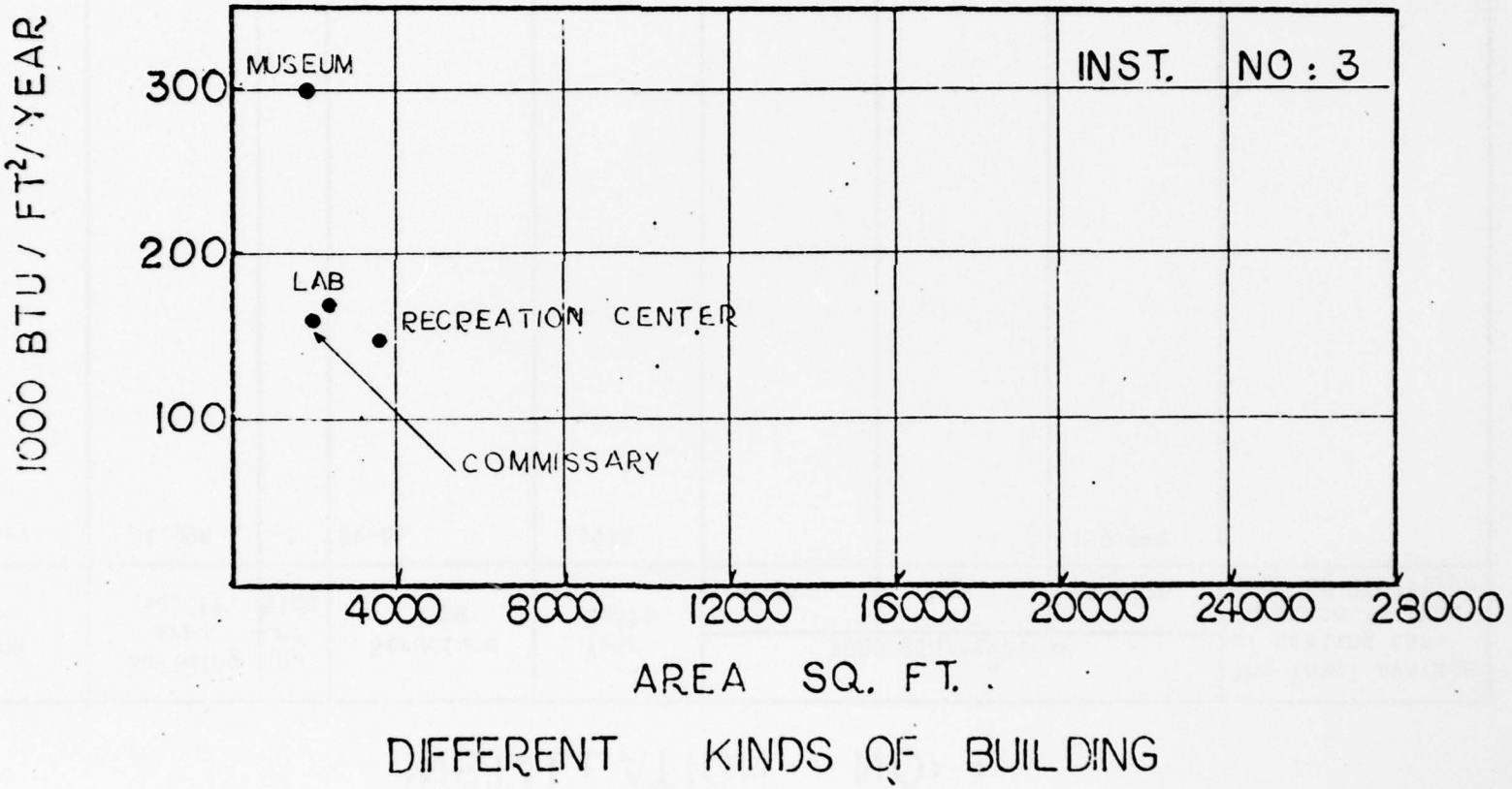
Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
Recreation Bldg	3,663	1	Wood-wood	1941			147.510	

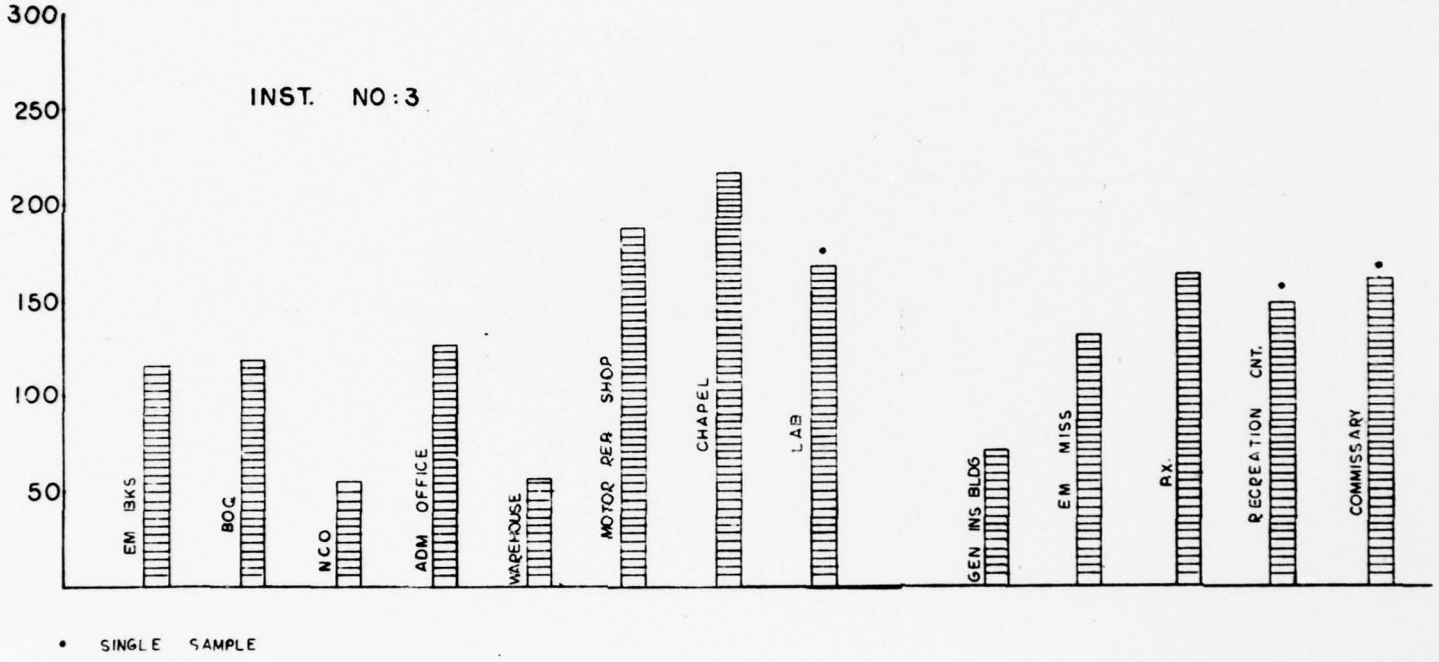
INSTALLATION NO: 3

Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
Museum	1,809	1	Tst-tst	1931			302.559	

INSTALLATION NO: 3

Building Type	Building area sq. ft.	no. of bldg	Structure Type	Year Built	1000 BTU/ft^2/year			The total average of heating consumption in thousands of BTU/ft^2/yr
					High	Low	Average	
Commissary	24,096	1	Bk-bk	1918			159.990	


1000 BTU / FT² / YEAR
300
200
100
MUSEUM
INST. NO : 3
LAB
RECREATION CENTER
COMMISSARY
4000
8000
12000
16000
20000
24000
28000
AREA SQ. FT.
DIFFERENT KINDS OF BUILDING


300
250
200
150
100
50
INST. NO: 3
EM BKS
BOQ
NCO
ADM OFFICE
WAREHOUSE
MOTOR REA SHOP
CHAPEL
LAB
GEN INS BLDG
EM MISS
PX
RECREATION CNT.
COMMISSARY
• SINGLE SAMPLE

APPENDIX D

CONCLUSIONS - COMBINED CONSUMPTION

Building Type	The average of heating consumption 1000 BTU/ft^2/year			The baseline heating consumption in thousands of BTU/ft^2/year
	Inst. #1	Inst. #2	Inst. #3	
Enlisted Men's Barracks	164.862	--	115.788	
weight	1		1.4	136.236
BOQ	89.810	111.786	117.315	
weight	4.3	1	2.7	101.840
Family Hs. for Officers	89.394	82.553	--	
weight	1	1.6		85.184
NCO	69.426	79.434	55.854	
weight	2	1	3	64.308

Building Type	The average of heating consumption 1000 BTU/ft^2/year			The baseline heating consumption in thousands of BTU/ft^2/year
	Inst. #1	Inst. #2	Inst. #3	
Administration Gen. Purp. Offices	84.431	77.101	126.222	
weight	4.9	3.9	1	85.778
Warehouse	109.457	129.346	56.503	
weight	1	1.7	2.2	92.582
Motor Repair Shop	270.293	91.990	187.884	
weight	1.3	1.6	1	176.013
Chapel	177.758	78.087*	216.779	
weight	2.3	1.4	1	156.371

*One building

Building Type	The average of heating consumption 1000 BTU/ft^2/year			The baseline heating consumption in thousands of BTU/ft^2/year
	Inst. #1	Inst. #2	Inst. #3	
Lab	98.506	--	167.155*	
weight	44		1	100.032
General Inst. Bldg.	128.838	--	70.689	
weight	8.4		1	122.652
Enlisted Men's Mess	101.589	58.486*	131.528	
weight	10.3	1	1.1	100.769
Enlisted Men's Barracks with Mess	87.851	93.373*	--	
weight	7.0	1		88.541

*One building

Building Type	The average of heating consumption 1000 BTU/ft^2/year			The baseline heating consumption in thousands of BTU/ft^2/year
	Inst. #1	Inst. #2	Inst. #3	
Post Exchange	117.334*	57.345*	162.370	
weight	1	4.6	3.7	105.580
Recreation Center	91.915*	--	147.510*	
weight	7.2		1	98.695
Theater	193.465*	274.733*	--	
weight	3.2	1		212.815
Commissary	19.008*	--	159.990*	
weight	5.4		1	41.036

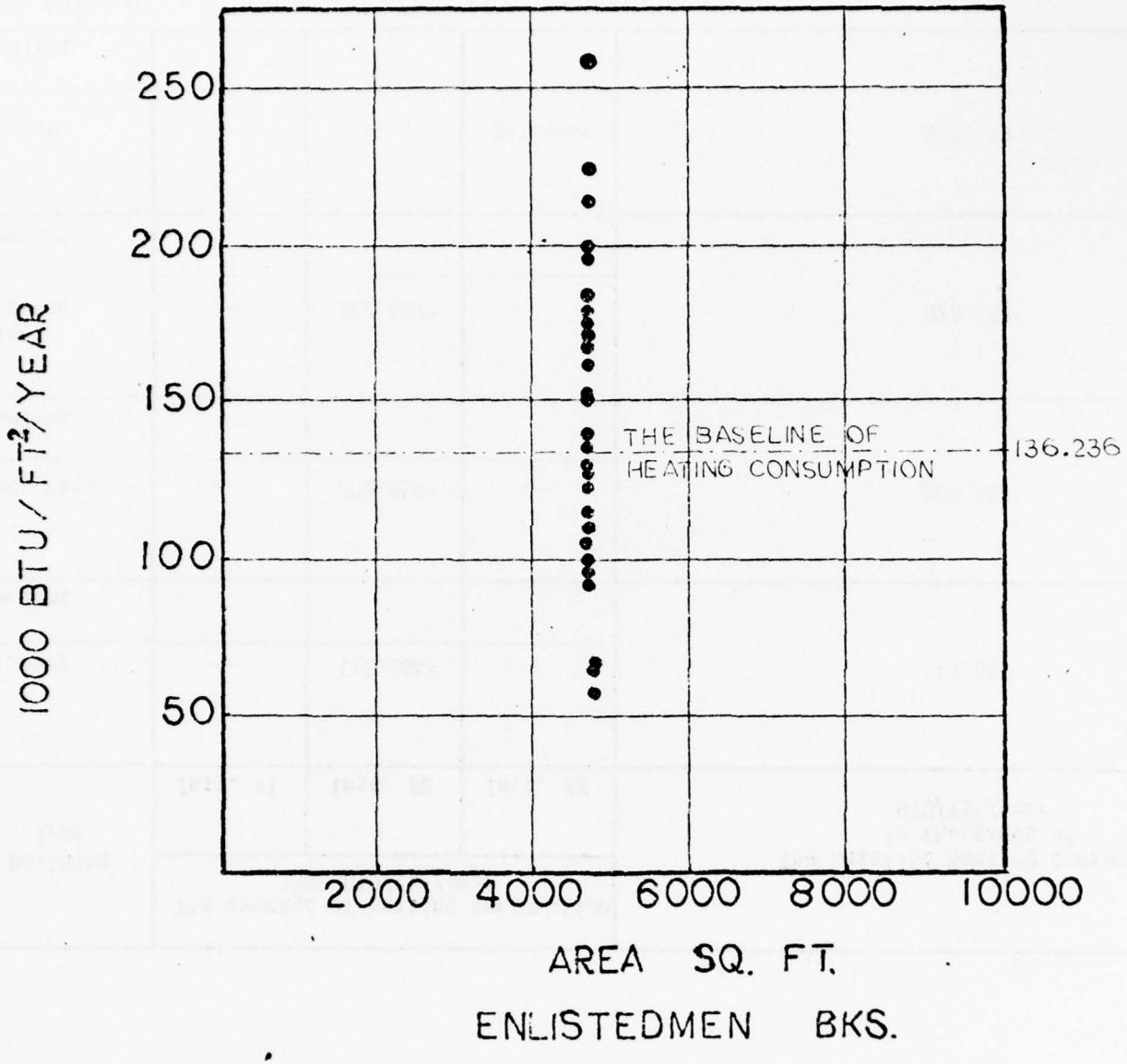
*One building

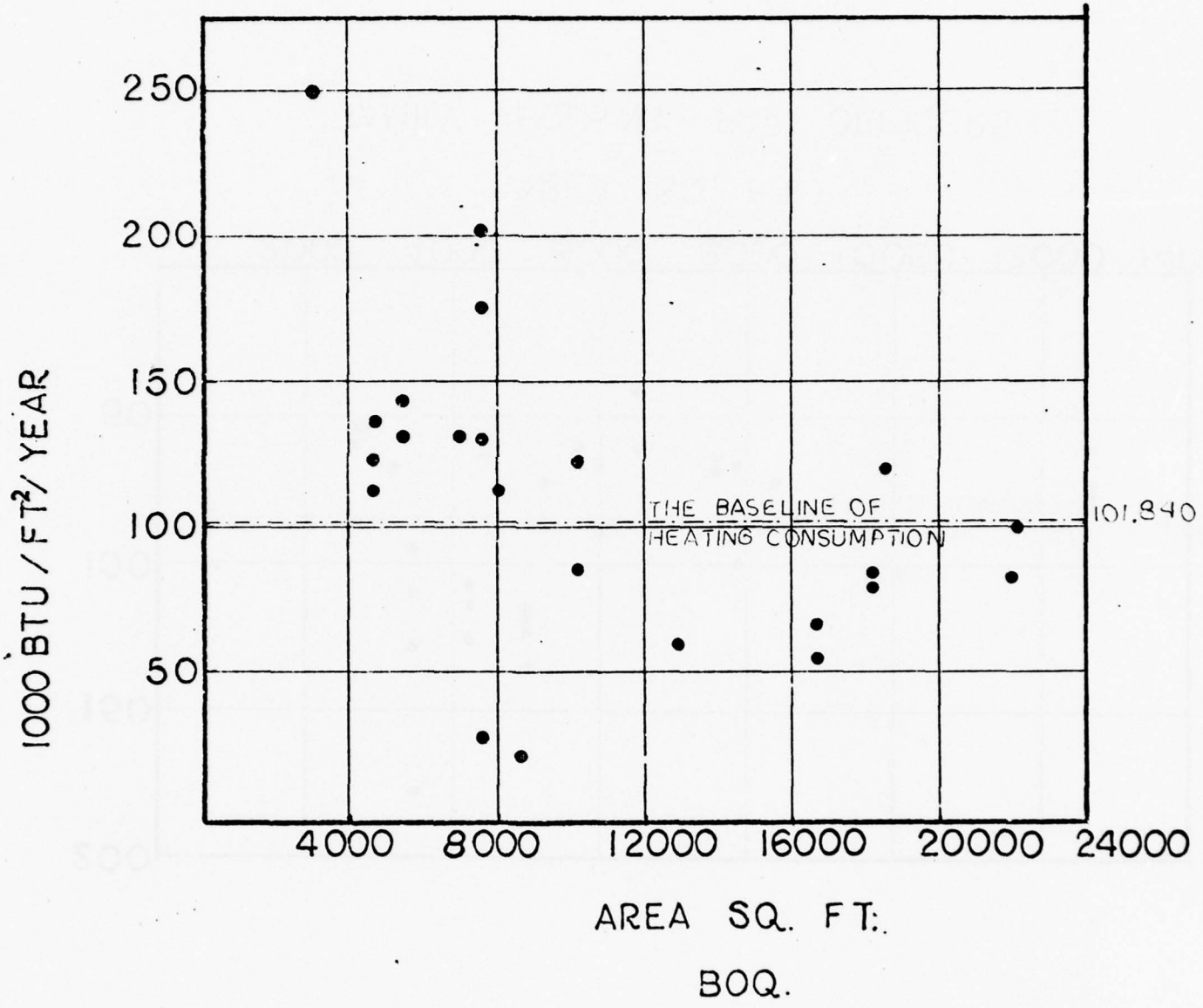
Building Type	The average of heating consumption 1000 BTU/ft^2/year			The baseline heating consumption in thousands of BTU/ft^2/year
	Inst. #1	Inst. #2	Inst. #3	
Bowling Alley	36.321*	--	--	36.321
weight				
Field House	168.908*			168.908
weight				
Officer's Mess	--	102.006*	--	102.006
weight				
Gymnasium	--	212.527*	--	212.527
weight				

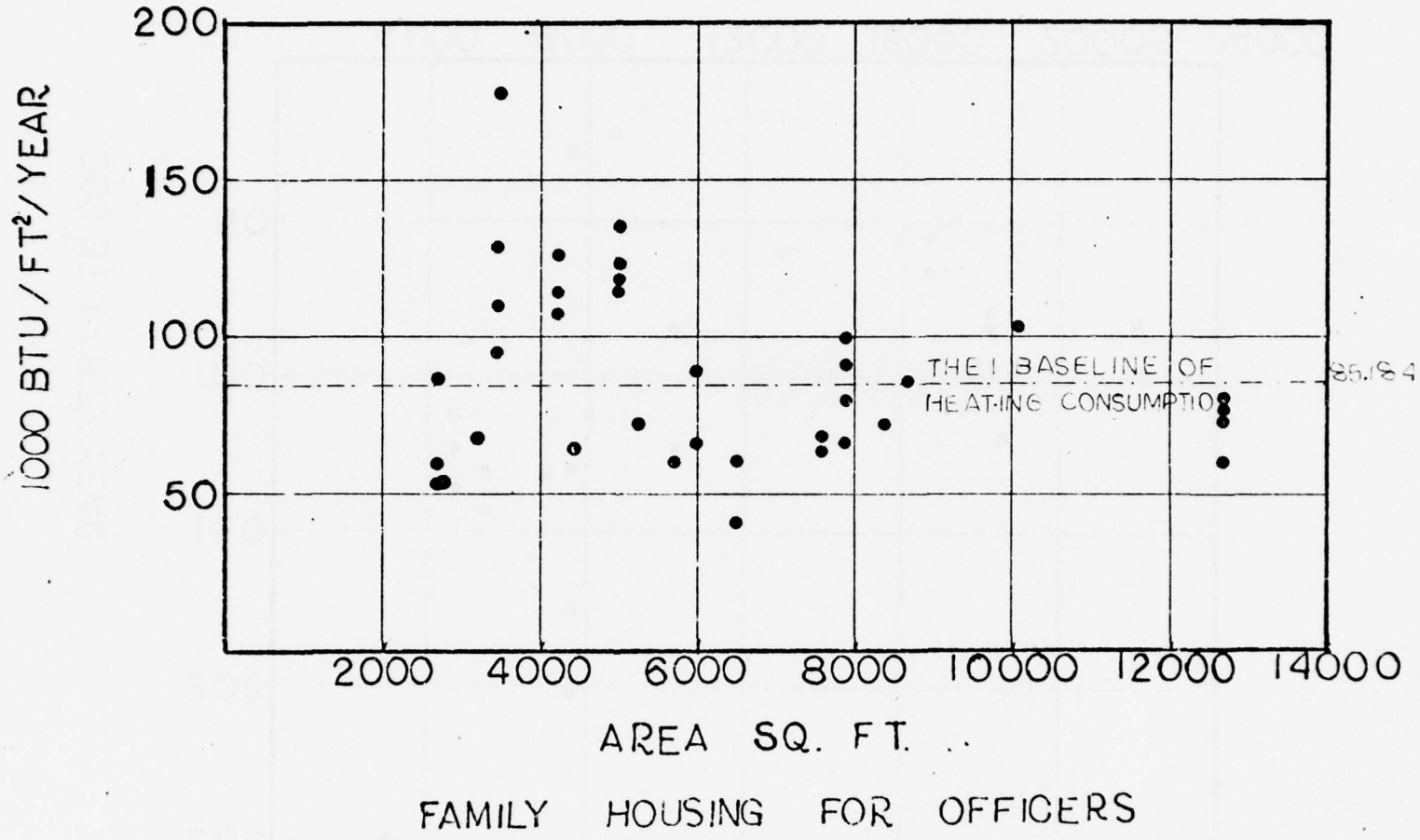
*One building

Building Type	The average of heating consumption 1000 BTU/ft^2/year			The baseline heating consumption in thousands of BTU/ft^2/year
	Inst. #1	Inst. #2	Inst. #3	
Library	--	117.064*	--	117.064
weight				
Aud. Band	--	209.854*	--	209.854
weight				
Fire Station	--	322.687*		322.687
weight				
Museum	--	--	302.559*	302.559
weight				

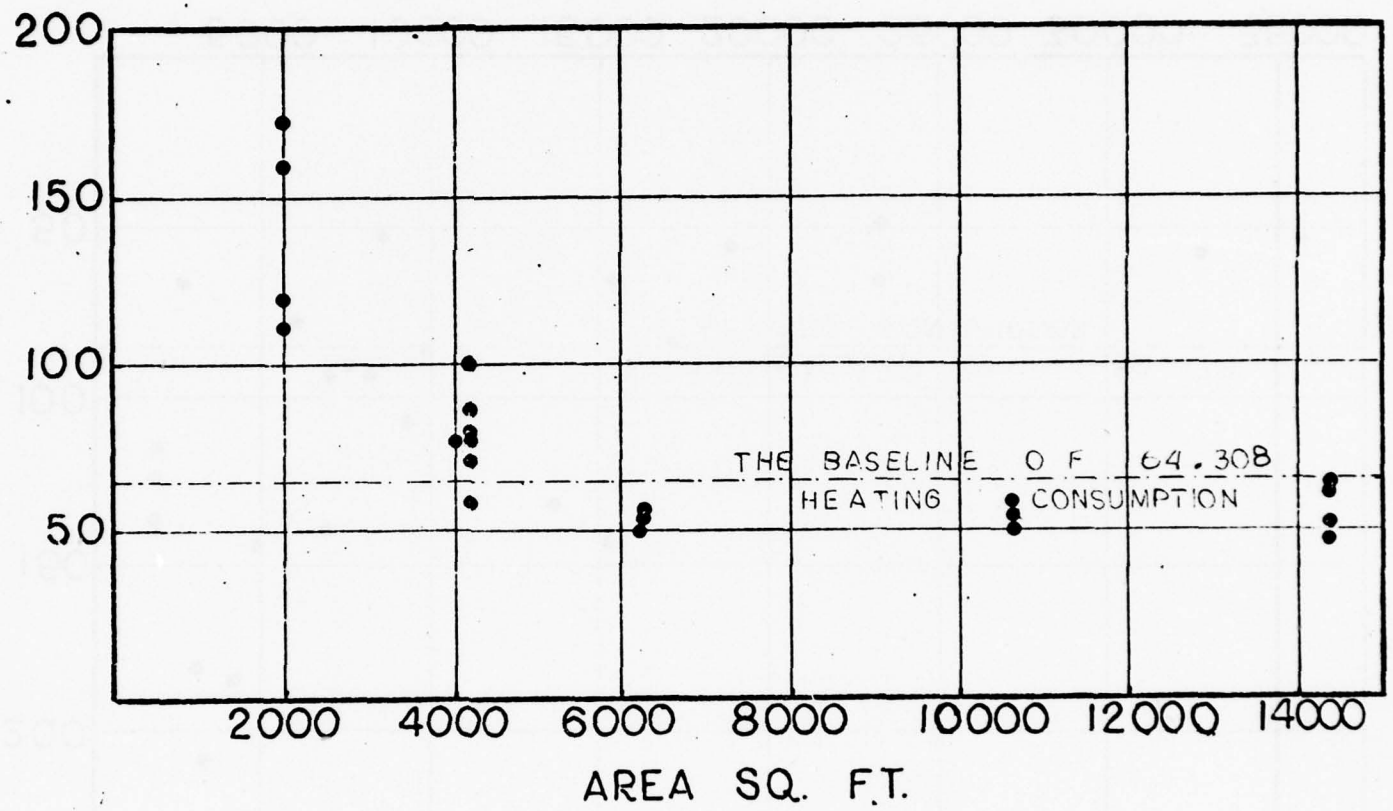
*One building


250
200
150
100
50
1000 BTU/FT²/YEAR
THE BASELINE OF
HEATING CONSUMPTION
136.236
2000
4000
6000
8000
10000
AREA SQ. FT.
ENLISTEDMEN BKS.

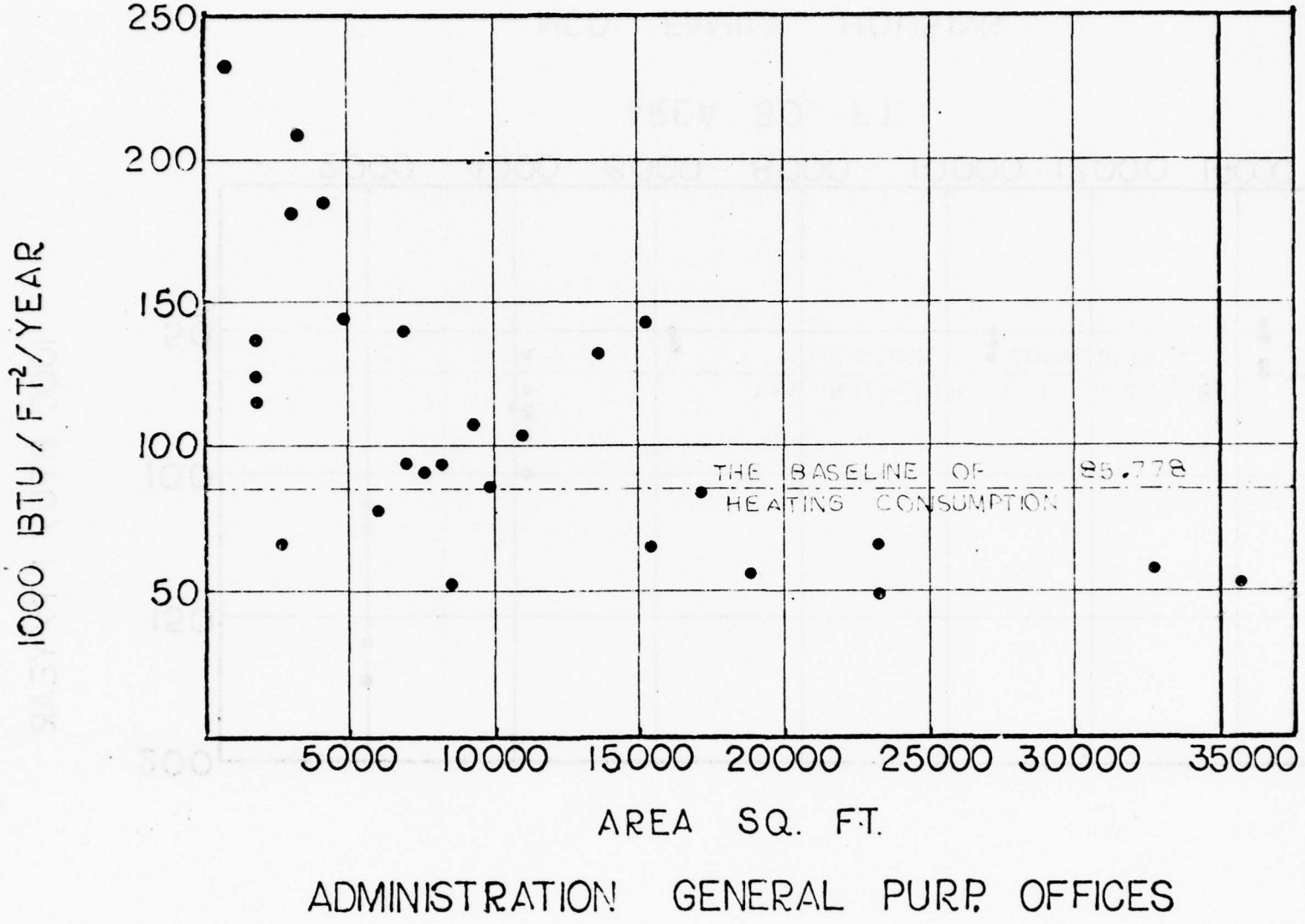

250
200
150
100
50
1000 BTU / FT² / YEAR
THE BASELINE OF
HEATING CONSUMPTION
101.840
4000
8000
12000
16000
20000
24000
AREA SQ. FT:
BOQ.



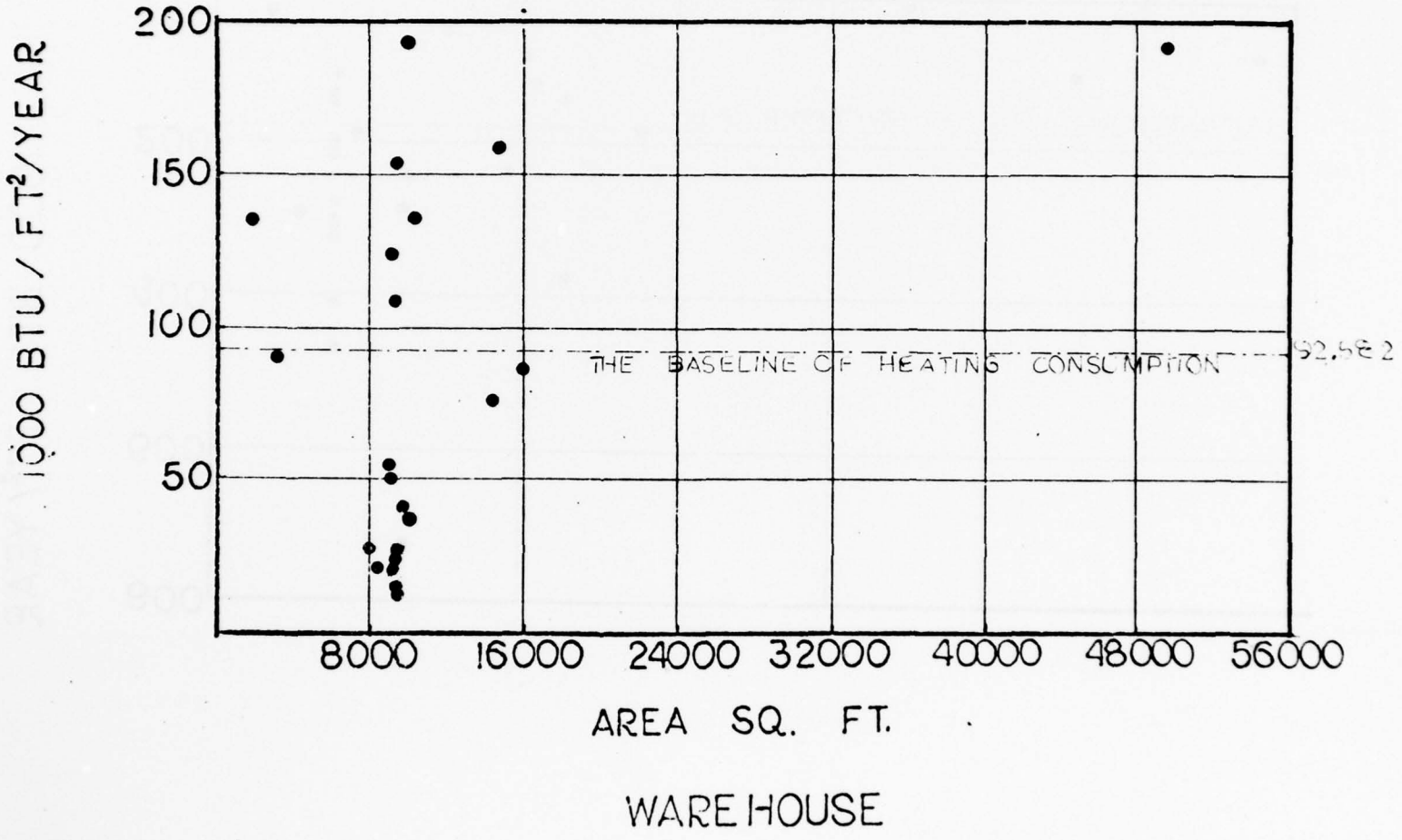
FAMILY HOUSING FOR OFFICERS

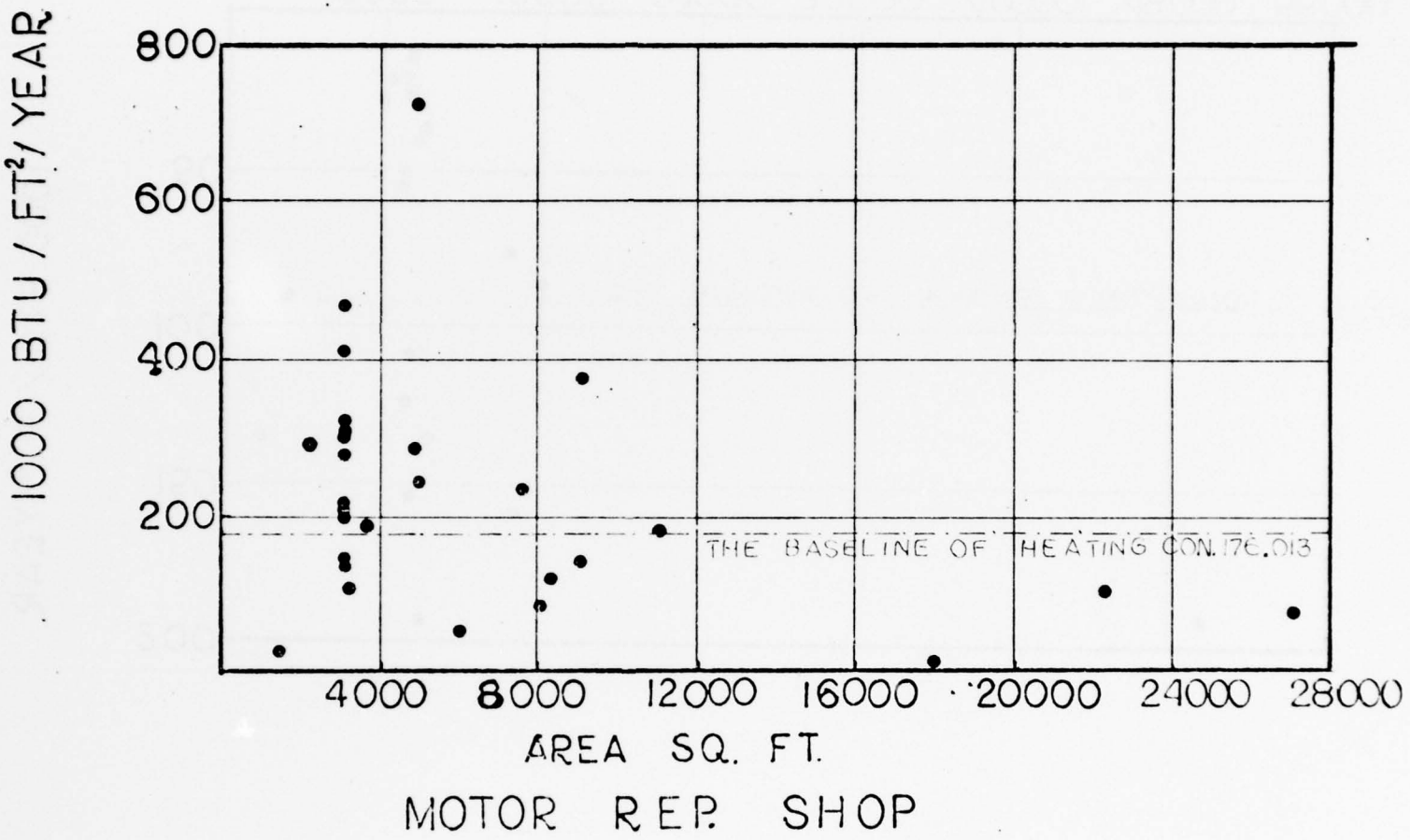


NCO FAMILY HOUSING

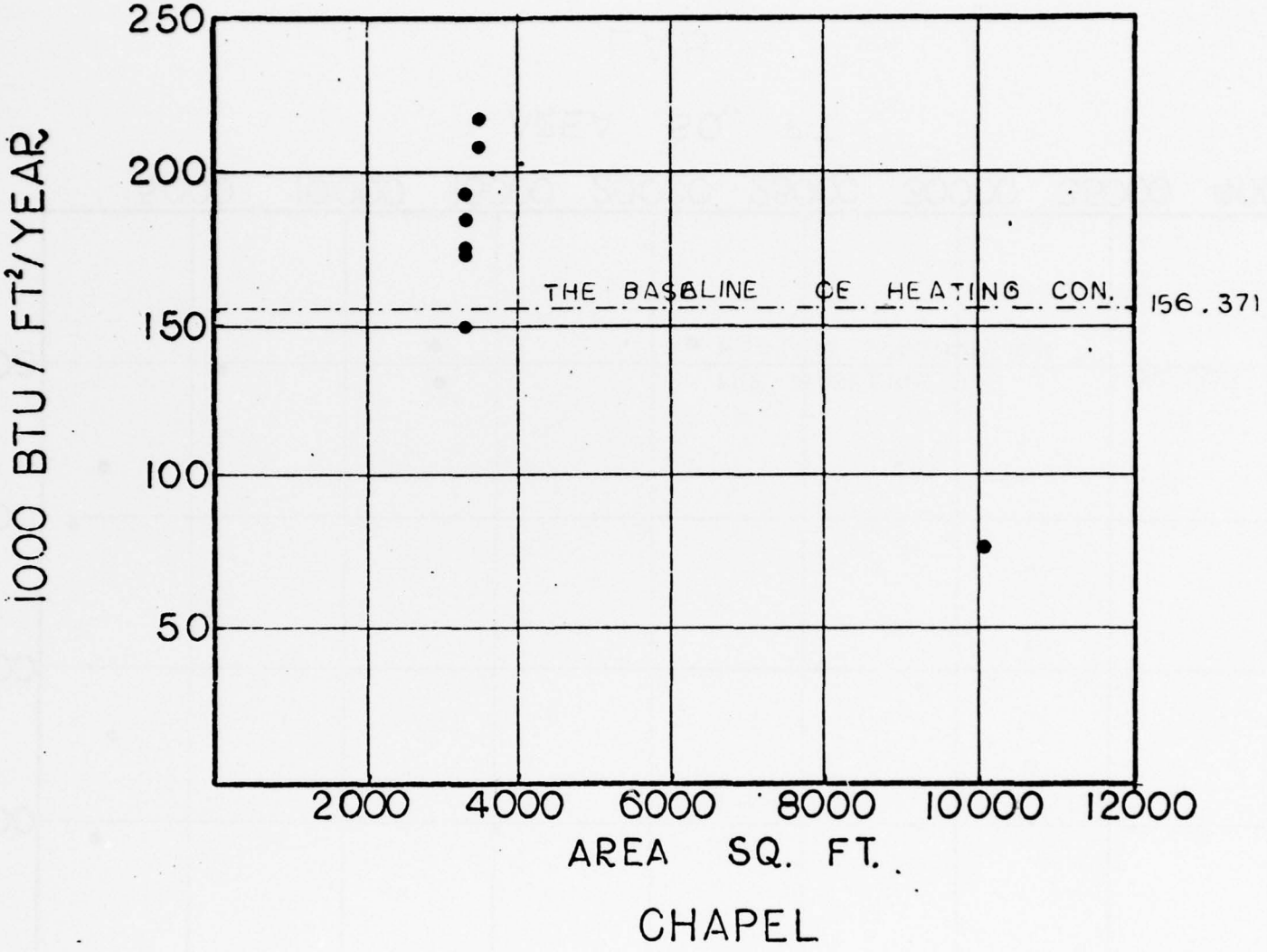


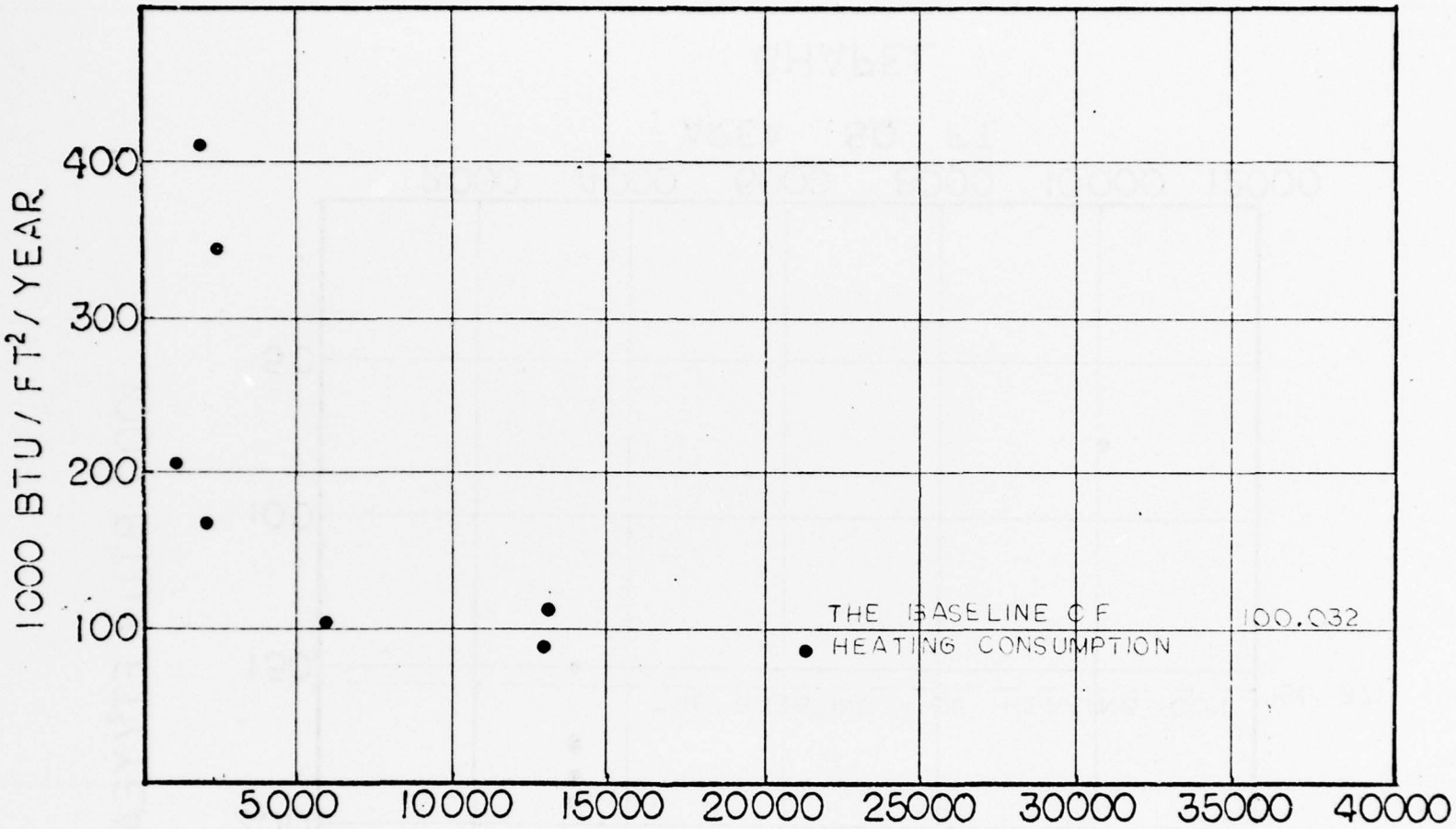
ADMINISTRATION GENERAL PURP. OFFICES


200
150
100
50
1000 BTU / FT²/YEAR
THE BASELINE OF HEATING CONSUMPTION
92.482
8000
16000
24000
32000
40000
48000
56000
AREA SQ. FT.
WAREHOUSE

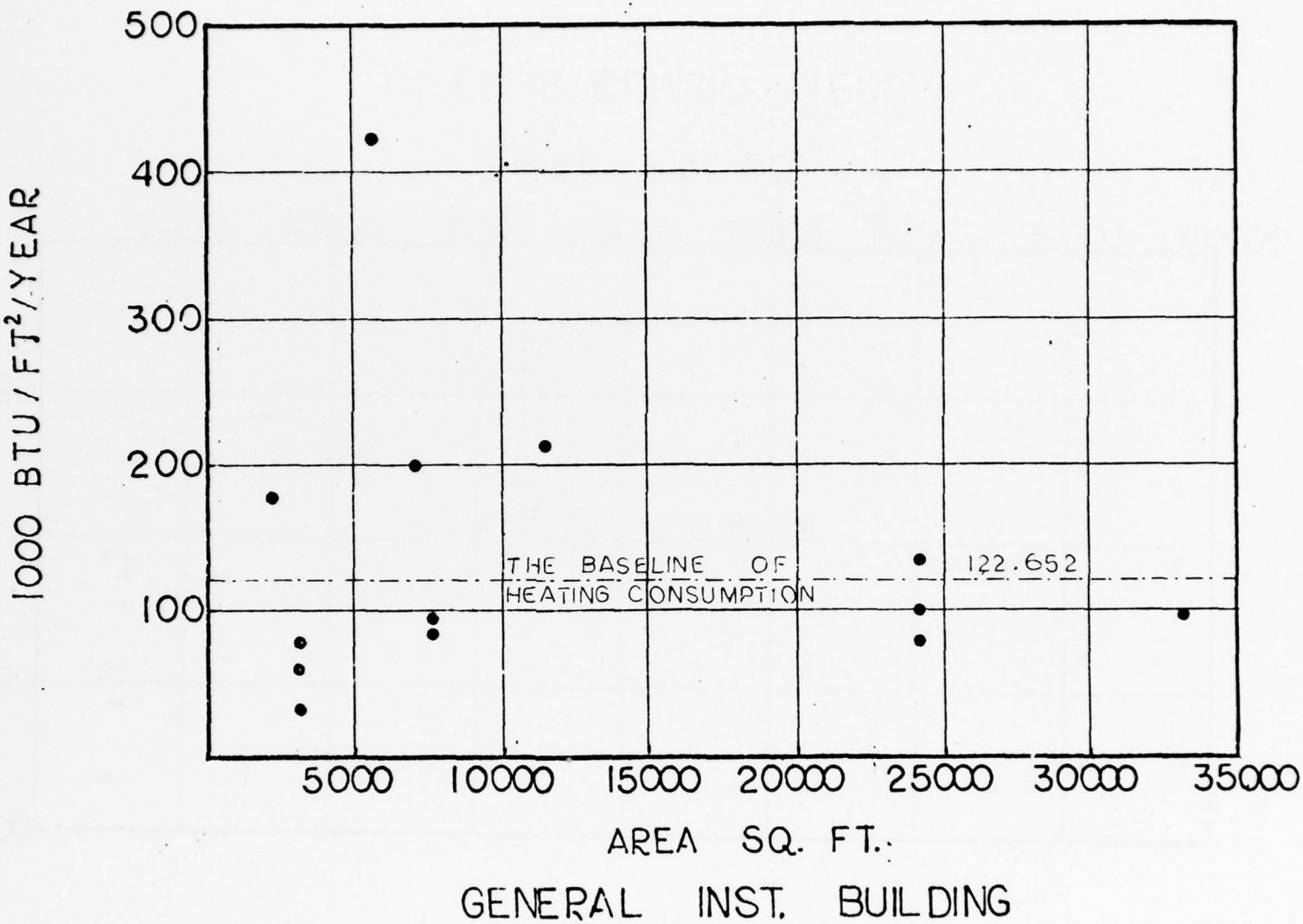


MOTOR REP. SHOP

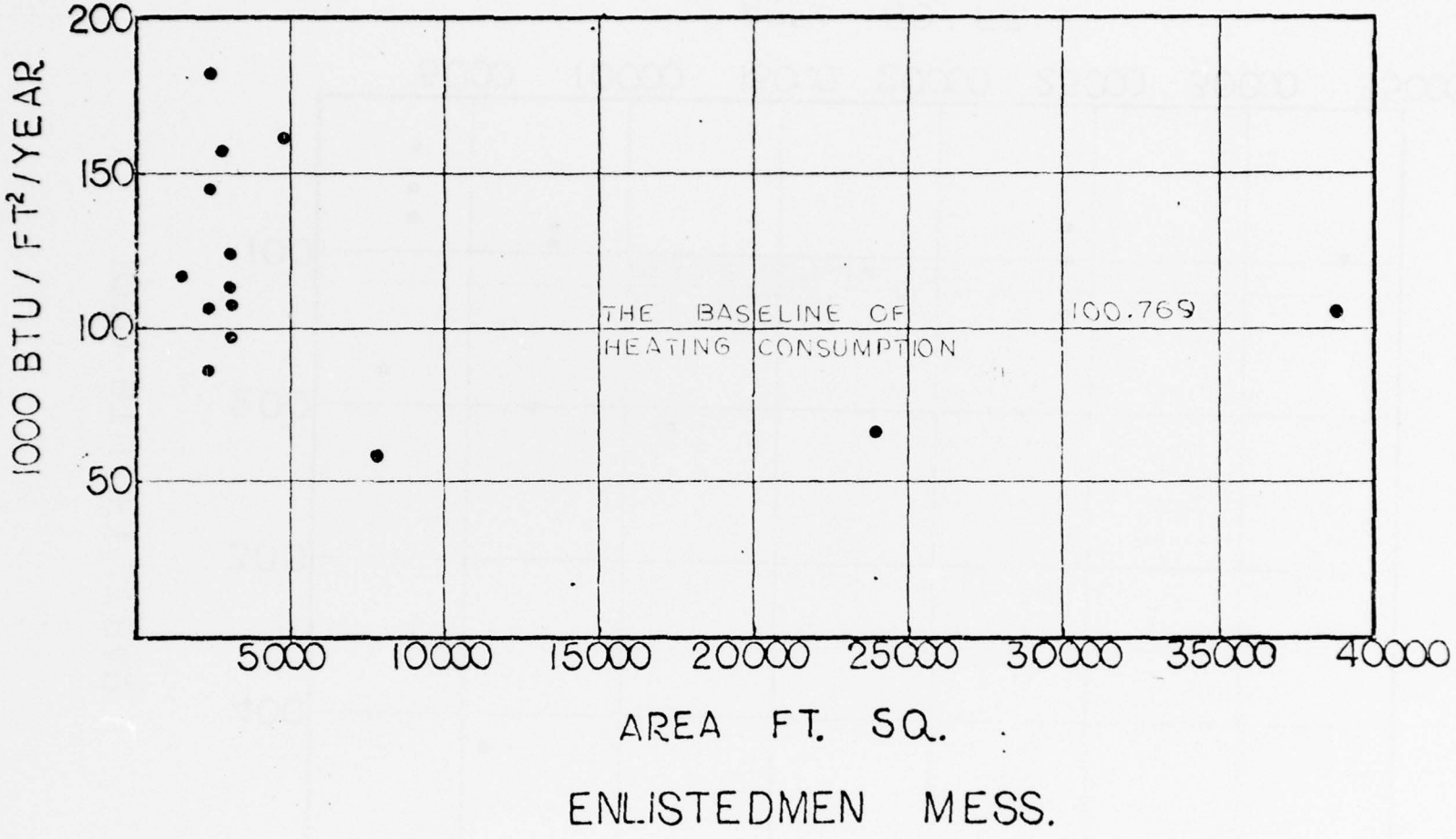

250
200
150
100
50
1000 BTU / FT²/YEAR
THE BASELINE CE HEATING CON.
156.371
2000
4000
6000
8000
10000
12000
AREA SQ. FT.
CHAPEL


1000 BTU / FT² / YEAR
400
300
200
100
5000
10000
15000
20000
25000
30000
35000
40000
AREA SQ. FT.
THE BASELINE OF
HEATING CONSUMPTION
100.032

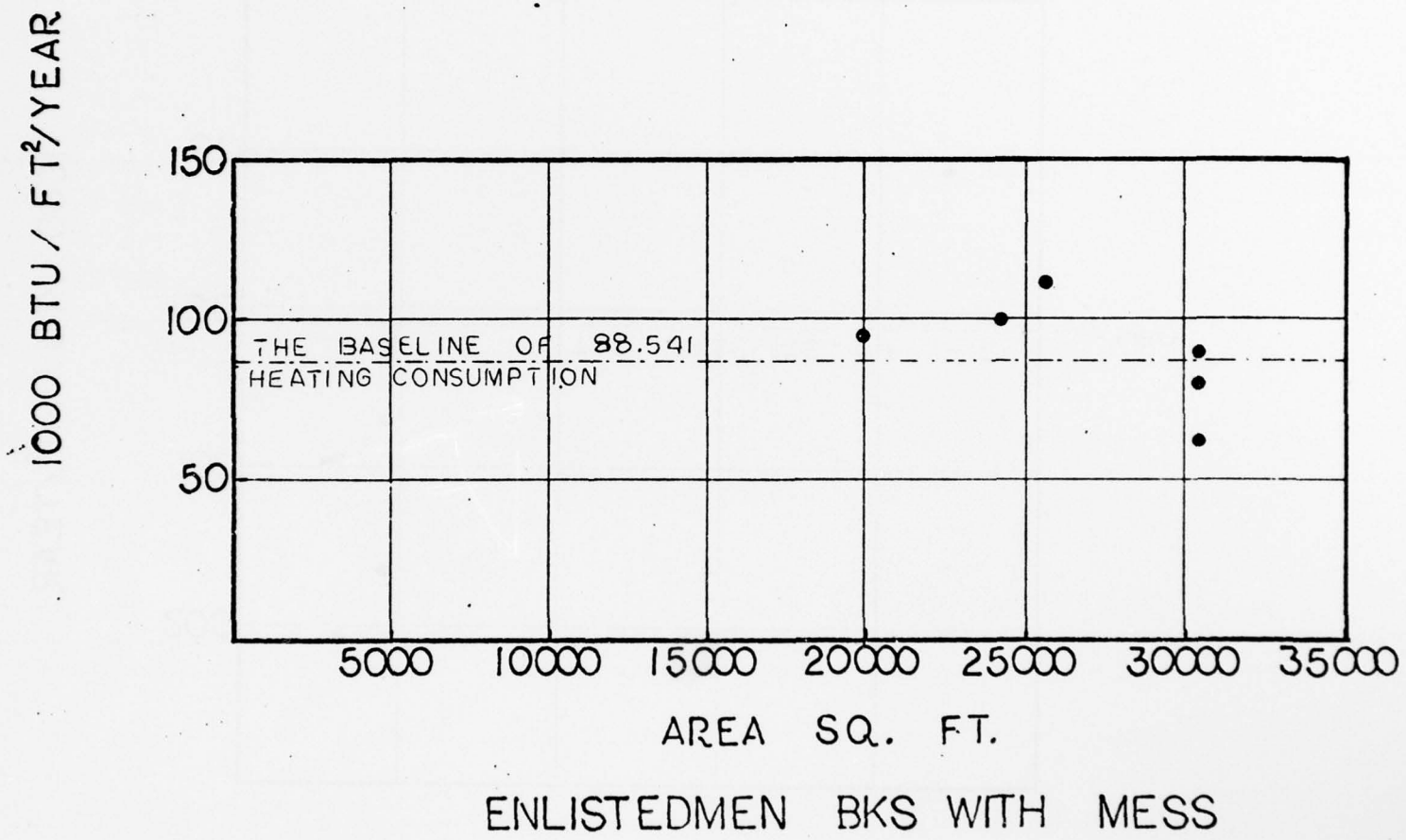
LAB



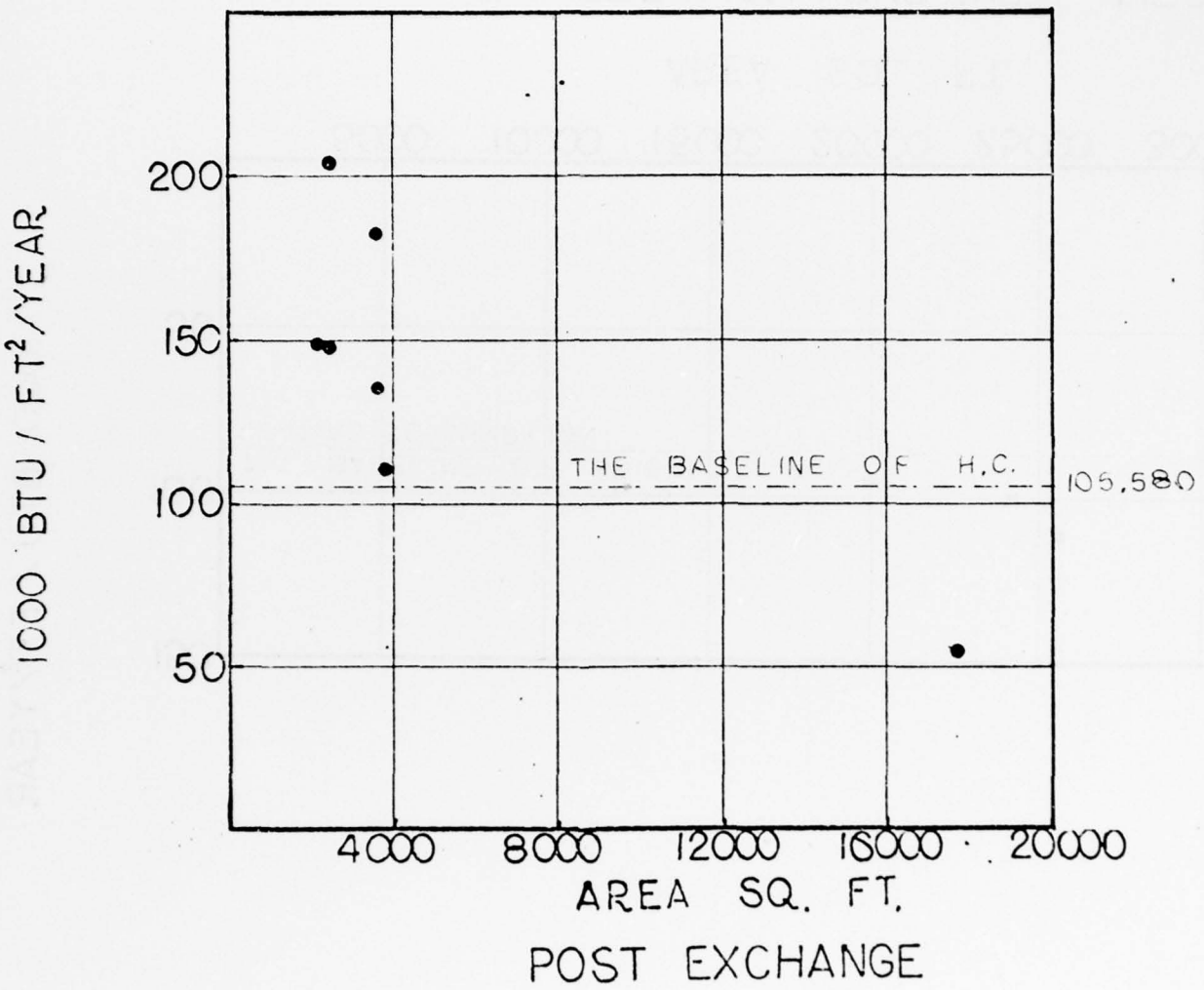
GENERAL INST. BUILDING

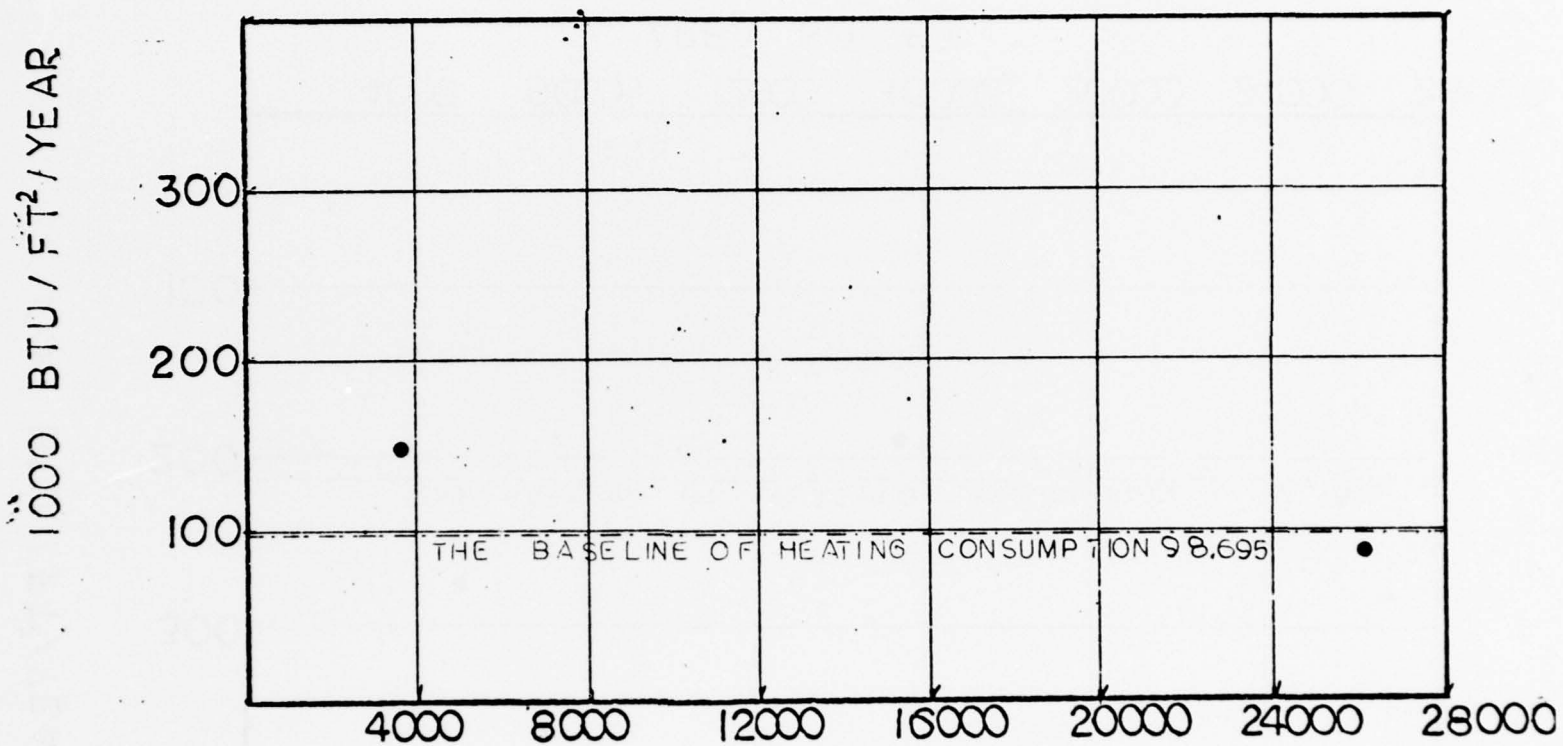


ENLISTEDMEN MESS.

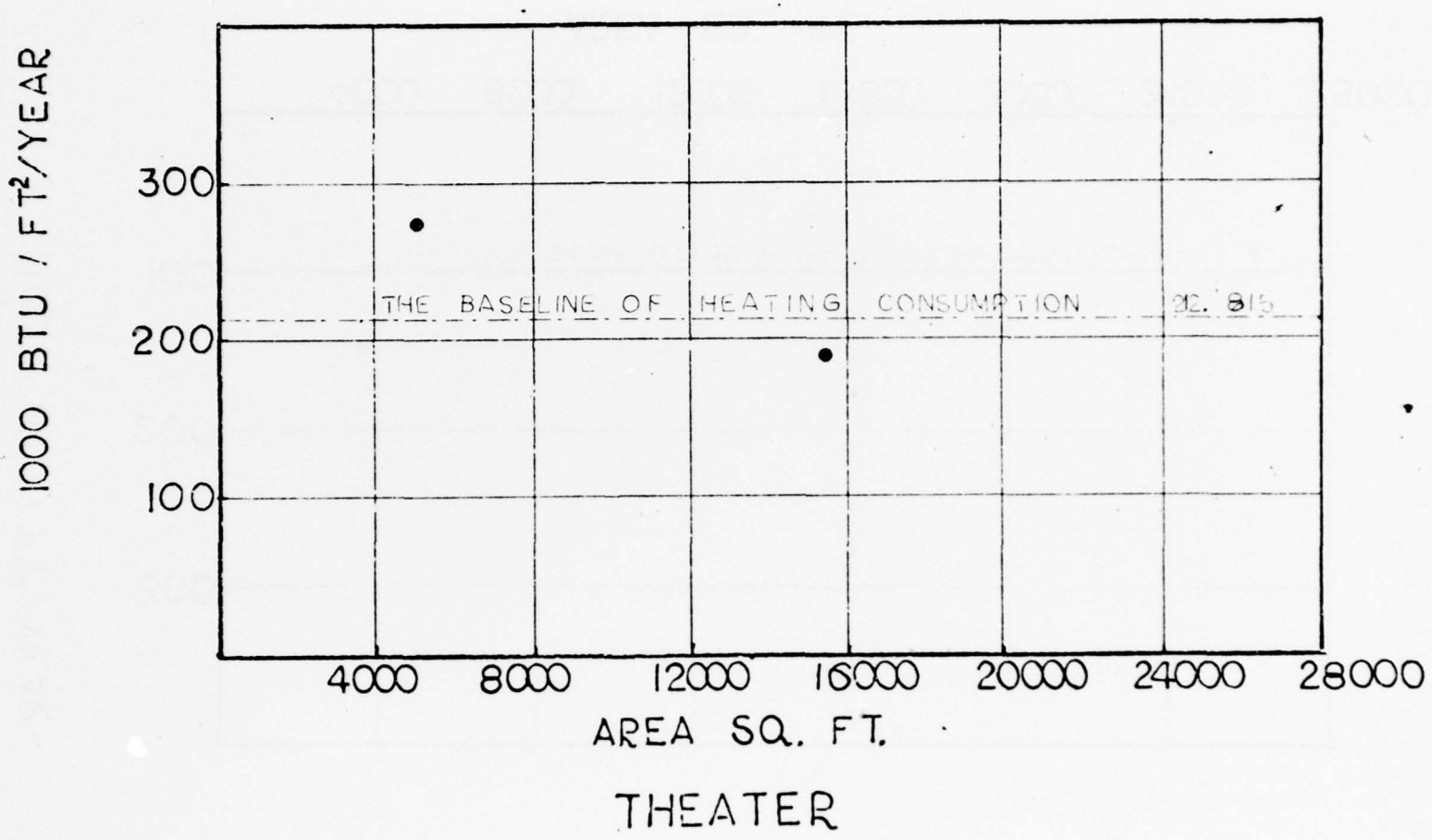


ENLISTEDMEN BKS WITH MESS

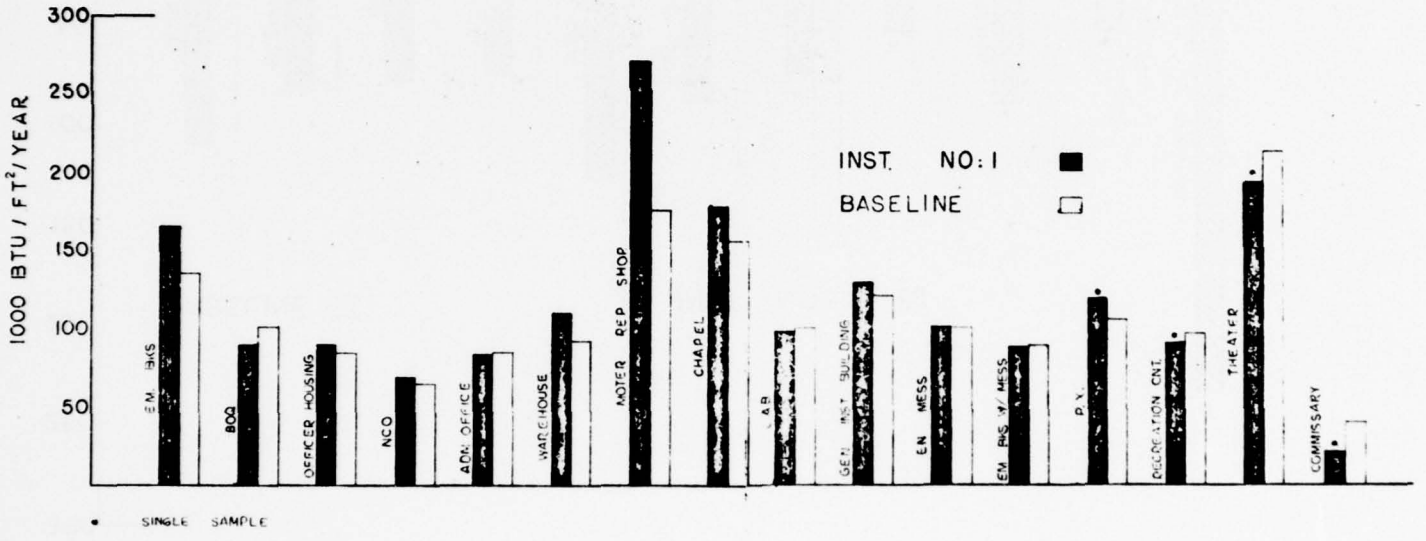

1000 BTU / FT²/YEAR
200
150
100
50
THE BASELINE OF H.C.
105,580
4000
8000
12000
16000
20000
AREA SQ. FT.
POST EXCHANGE

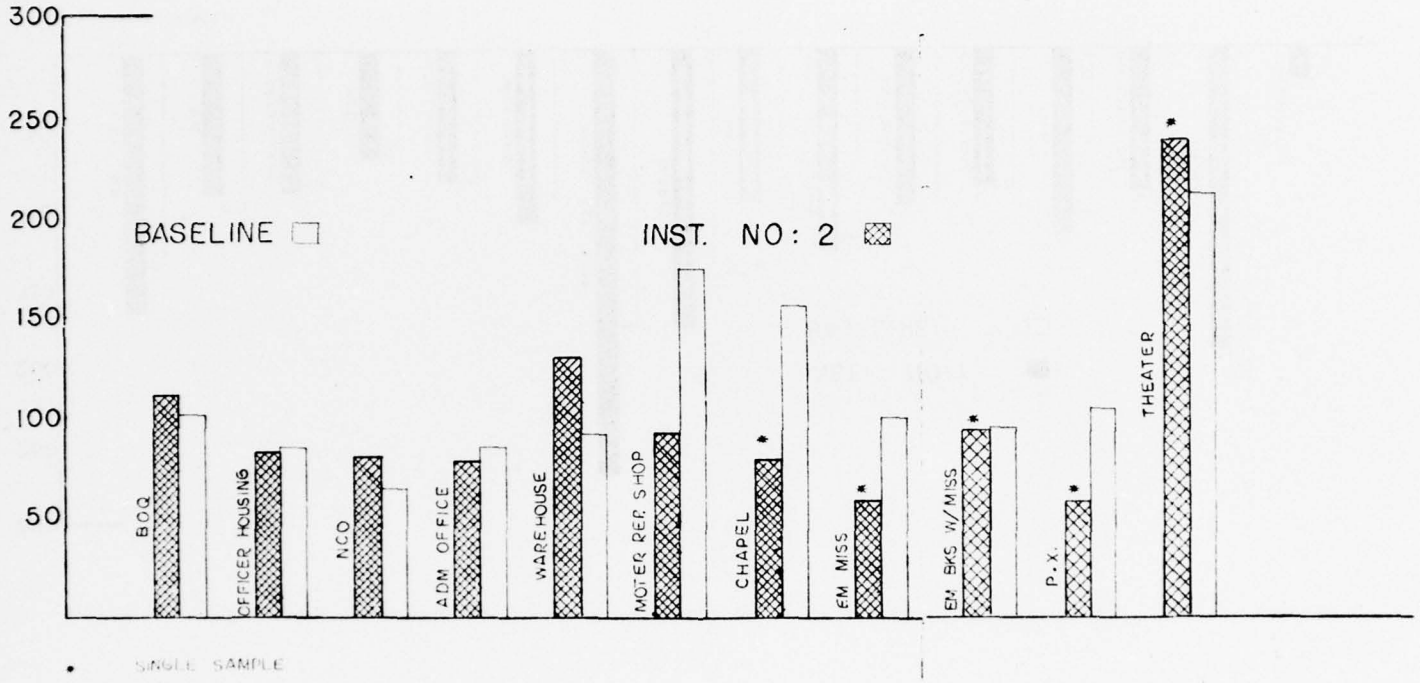


RECREATION CENTER


1000 BTU / FT²/YEAR
300
200
100
THE BASELINE OF HEATING CONSUMPTION
4000
8000
12000
16000
20000
24000
28000
AREA SQ. FT.

THEATER


1000 BTU / FT² / YEAR
300
250
200
150
100
50
INST. NO: 1
BASELINE
E.M. BKS
BOQ
OFFICER HOUSING
NCO
ADM. OFFICE
WAREHOUSE
MOTER REP SHOP
CHAPEL
A.R.
GEN. INST. BUILDING
EN MESS
EM BKS. W/ MESS
P.X.
RECREATION CNT.
THEATER
COMMISSARY
• SINGLE SAMPLE


300
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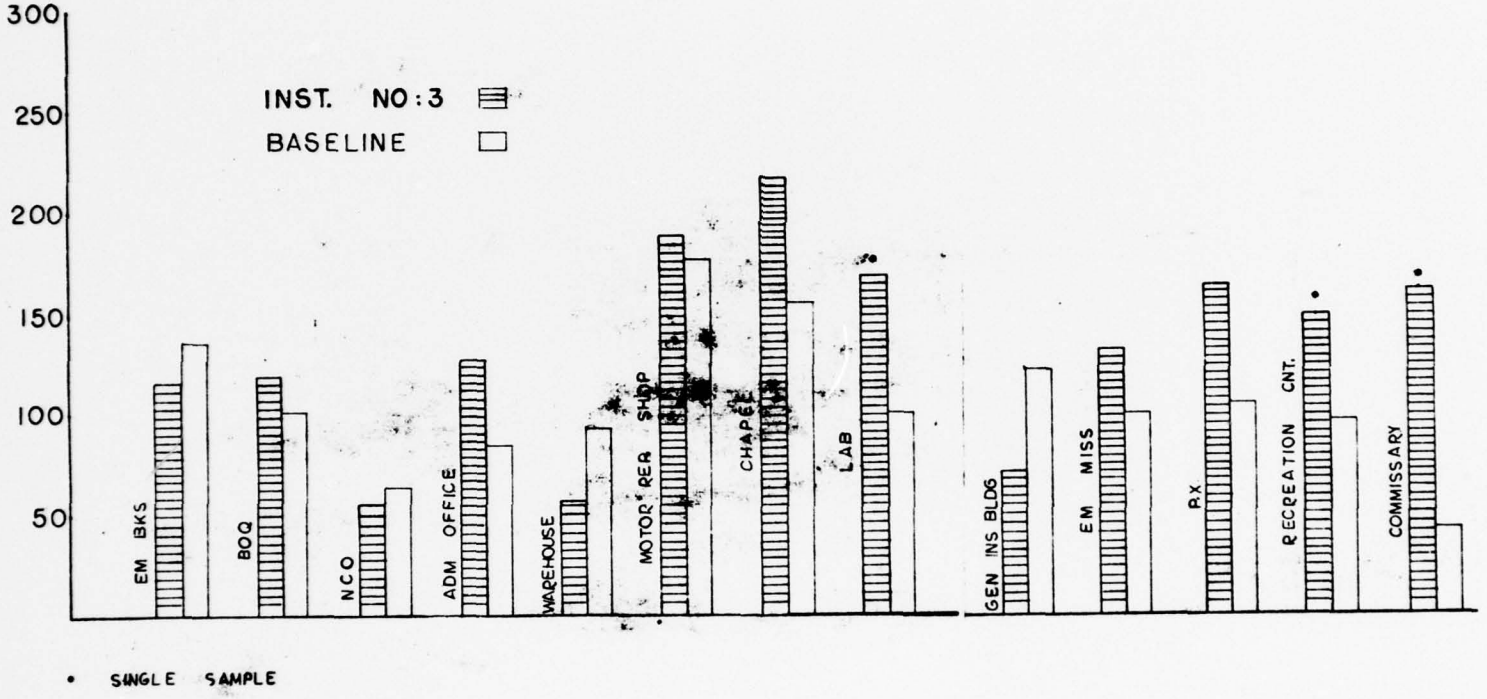
100
50
BASELINE
INST. NO: 2
BOQ
OFFICER HOUSING
NCO
ADM OFFICE
WAREHOUSE
MOTER REP. SHOP
CHAPEL
EM MESS
EM BKS W/MESS
P.X.
THEATER
* SINGLE SAMPLE


300
250
200
150
100
50
INST. NO:3
BASELINE
EM BKS
BOQ
NCO
ADM OFFICE
WAREHOUSE
MOTOR POOL
SHOP
CHAPEL
LAB
GEN INS BLDG
EM MISS
PX
RECREATION CNT.
COMMISSARY
• SINGLE SAMPLE

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